SEWAGE AND INDUSTRIAL WASTES

(Formerly Sewage Works Journal)

JOURNAL of the FEDERATION OF SEWAGE AND INDUSTRIAL WASTES ASSOCIATIONS

Special Features

Corrosion Studies at Baltimore—Keefer and Huston

Aeration Efficiency—Eckenfelder

Cyanide Determination—Kruse and Mellon

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OCTOBER, 1952—VOL. 24, No. 10

Make Plans to Attend

TWENTY-SIXTH ANNUAL MEETING

OF THE

FEDERATION OF SEWAGE AND INDUSTRIAL WASTES ASSOCIATIONS

IN CONJUNCTION WITH

FLORIDA SEWAGE AND INDUSTRIAL WASTES ASSOCIATION

MUNICIPAL (BAYFRONT PARK) AUDITORIUM

MIAMI, FLORIDA

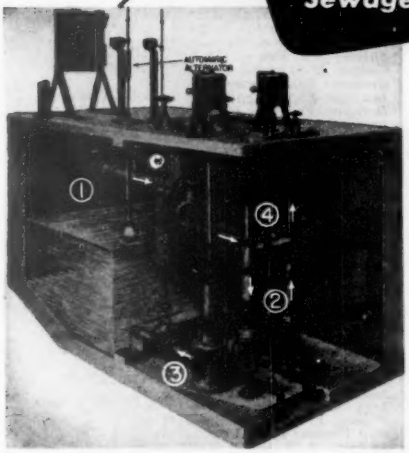
October 13-16, 1953

FEDERATION OF SEWAGE AND INDUSTRIAL WASTES ASSOCIATIONS

325 ILLINOIS BUILDING CHAMPAIGN, ILLINOIS

Chicago FLUSH-KLEEN Sewage Ejectors

Over 12,000 In Service



Flush-Kleens are absolutely clog proof. Here are the reasons why: Flush-Kleen pumps automatically backwash the strainers, keeping solids from basin and pumps, with the impellers handling water only —this is accomplished as follows:

FILLING WET WELL . . . 1. Sewage flows through inlet pipe. 2. Coarse matter is retained on strainer. 3. Strained sewage flows through idle pump to wet well.

PUMPING . . . 3. Strained sewage is pumped from wet well. 2. Coarse matter is backwashed from strainer. 4. Special check valve closes; sewage and coarse matter are pumped to sewers.

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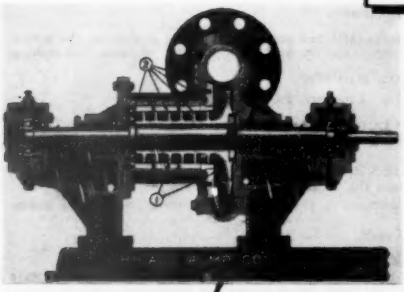
Chicago SCRU-PELLER Sludge Pumps

More Than 8,000 In Use



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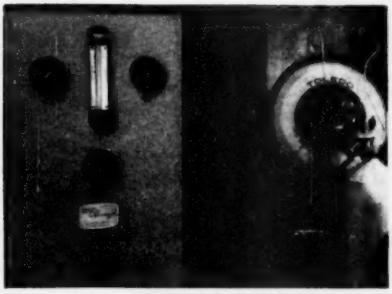

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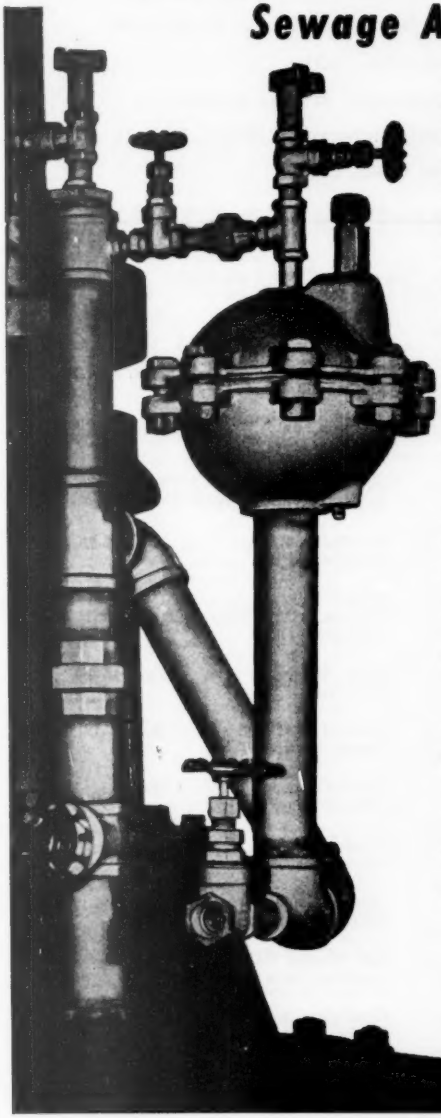

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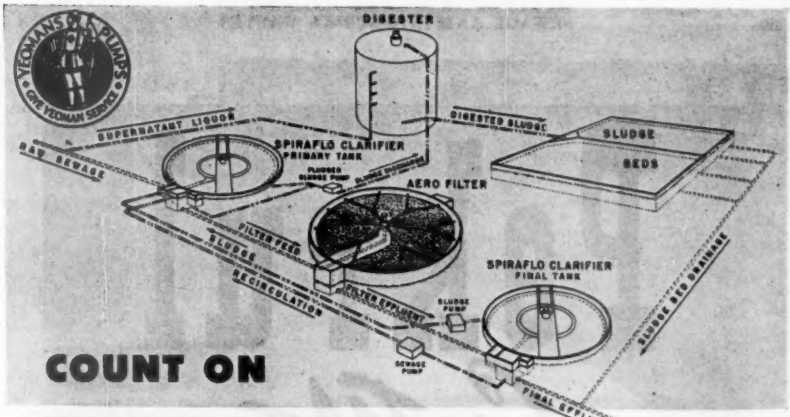
October 13–16, 1953

Association	*Place*	*Time*
Pacific Northwest Sewage and Industrial Wastes Assn.	Multnomah Hotel, Portland, Ore.	Oct. 23–24, 1952
The Canadian Institute on Sewage and Sanitation	Seigniory Club, Montebello, Que.	Nov. 3–5, 1952
New England Sewage and Industrial Wastes Assn.	Taunton Inn Taunton, Mass.	Nov. 5, 1952
North Carolina Sewage and Industrial Wastes Assn.	Skyland Hotel, Hendersonville, N. C.	Nov. 10–12, 1952
Florida Sewage and Industrial Wastes Assn.	San Carlos Hotel, Pensacola, Fla.	Nov. 16–19, 1952
Oklahoma Water, Sewage and Industrial Waste Conference	Student Union, Okla. A & M College, Stillwater, Okla.	Dec. 1–5, 1952
New York Sewage and Industrial Wastes Assn.	Hotel Statler, New York City	Jan. 15–16, 1953
Texas Water and Sewage Works Assn.	Texas A & M College, College Station, Tex.	Mar. 8–12, 1953
New Jersey Sewage and Industrial Wastes Assn.	Hotel Traymore, Atlantic City, N. J.	March 11–13, 1953
Arkansas Water and Sewage Conference	Hotel Marion, Little Rock, Ark.	Mar. 16–18, 1953
South Carolina Water and Sewage Works Assn.	Clemson College, Spartansburg, S. C.	Apr. 2–4, 1953
Arizona Sewage and Water Works Assn.	San Marcos Hotel, Chandler, Ariz.	Apr. 23–25, 1953
Central States Sewage and Industrial Wastes Assn.	Hotel Pere Marquette, Peoria, Ill.	June 3–5, 1953
Pennsylvania Sewage and Industrial Wastes Assn.	Pa. State College, State College, Pa.	Aug. 26–28, 1953



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6-16	0.2467	425	260	85	80.0	127	51.2	23	73.0	19	85.1	94.6	92.6
6-17	0.2554	410	235	124	69.7	141	40.0	28	77.4	18	87.3	93.3	92.4
6-18	0.2487	306	215	76	75.4	108	51.4	34	55.3	16	85.2	89.0	92.8
6-19	0.1753	222	218	64	71.2	132	39.5	17	73.5	—	—	92.4	—
6-20	0.2666	262	320	88	66.4	147	54.1	20	77.3	30	79.6	92.4	90.6
6-21	0.2279	240	215	78	67.5	138	35.8	19	75.7	20	85.7	92.0	90.7
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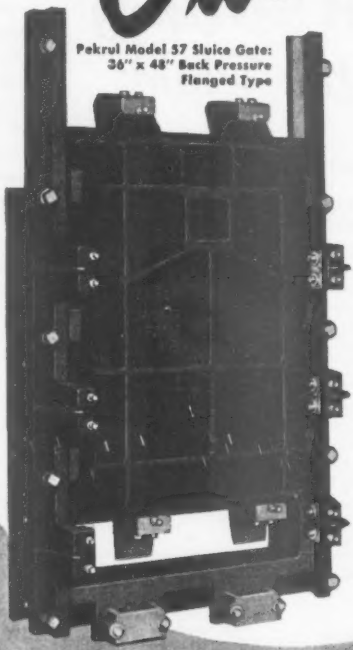

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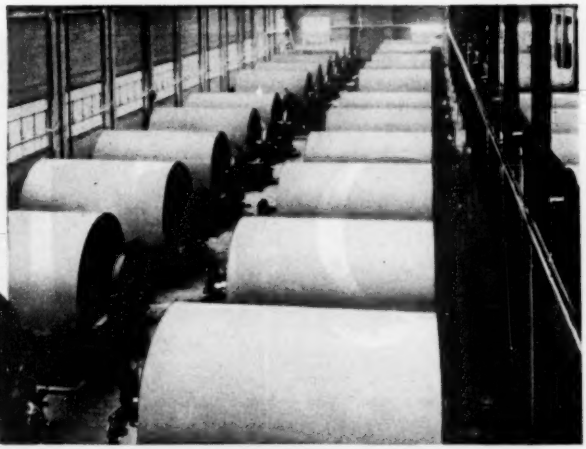

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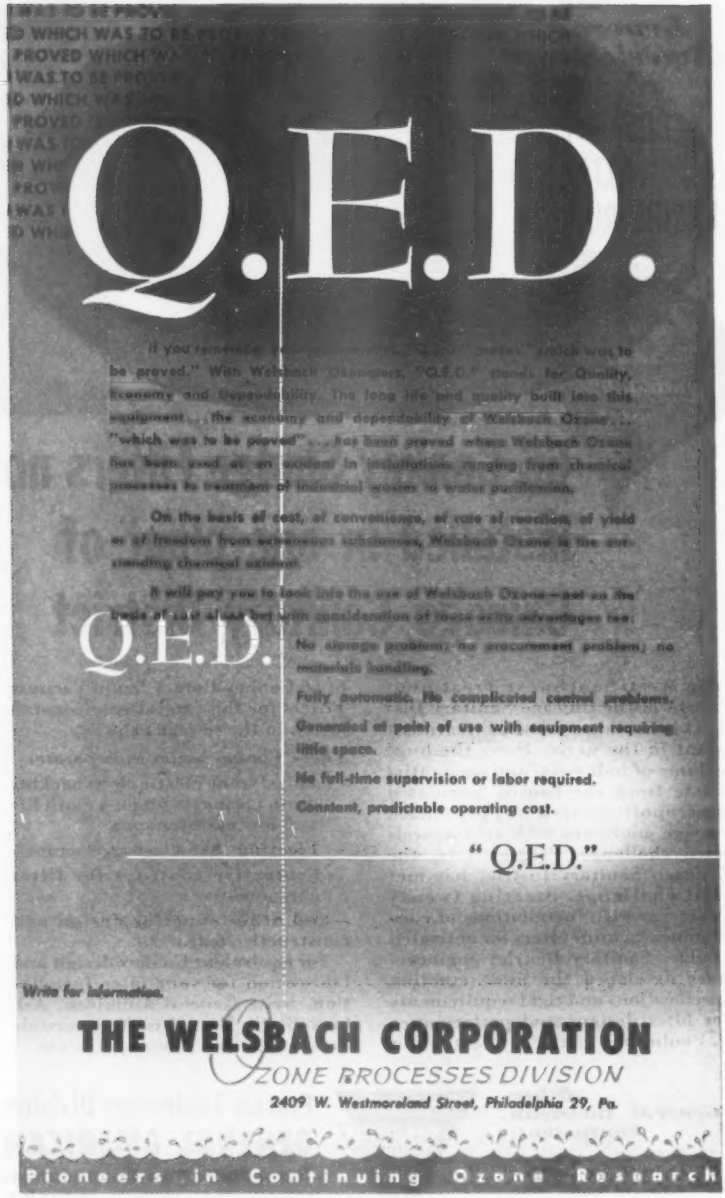
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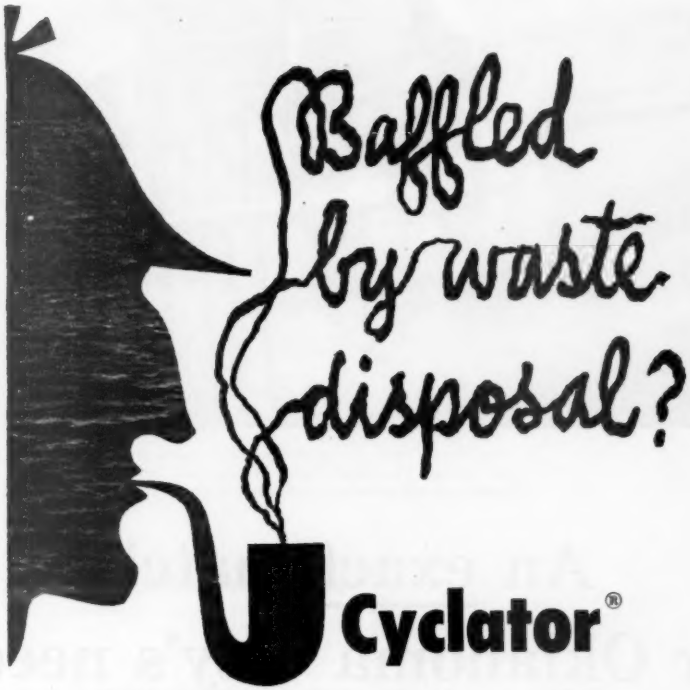

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Looking for clues for the effective removal of oils, light suspended solids and toxic metals? Then investigate the Cyclator.

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Ask for complete information including Cyclator case histories. Available in our Bulletin 850.

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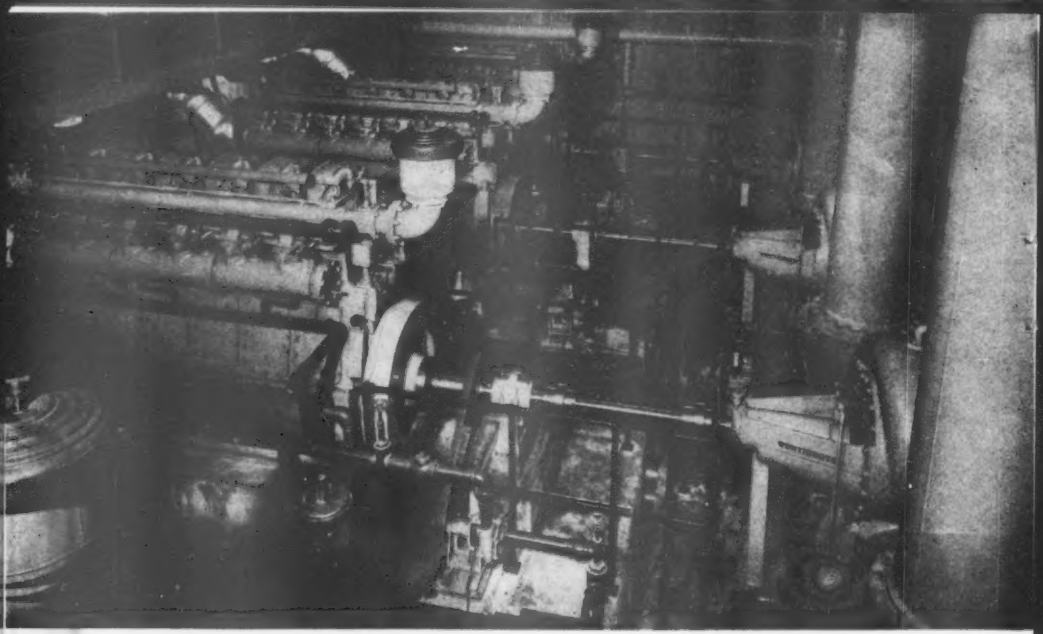


FOUR 20-MGD CENTRIFUGAL PUMPS (right) pump raw sewage into Oklahoma City's South side Sewage Treatment Plant. Worthington Sewage Gas Engines (left) drive pumps. Installation uses three other such pumps for recirculation, also driven by Worthington engines.

An exact match for Oklahoma City's needs

The right *equipment for new sewage plant selected from Worthington's complete line*

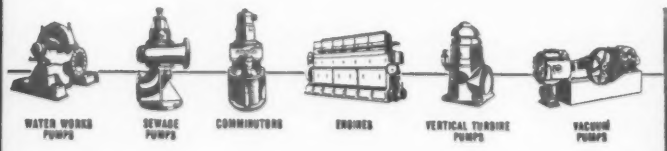
An outstanding job in every way. That's what they're all saying about the new Southside Sewage Treatment Plant at Oklahoma City.

Seven giant Worthington 20-mgd centrifugal pumps used for pumping raw sewage and recirculation are driven by Worthington gas-engines that are fueled by methane gas from raw sewage.

Oklahoma City's modern plant—like virtually every municipal installation—had *special* requirements. They met these requirements with Worthington equipment—engines, pumps, and other apparatus such as air compressors.

To municipalities like Oklahoma City, Worthington means getting *all* major public work equipment under *one* responsibility. Engines for any available fuel, the world's most complete line of pumps, comminutors, air compressors, water treating equipment, motors, and power-transmission equipment.

Write us—learn all the reasons why *there's more worth in Worthington.* Worthington Corporation, Public Works Division, Harrison, N. J.



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Superior specified

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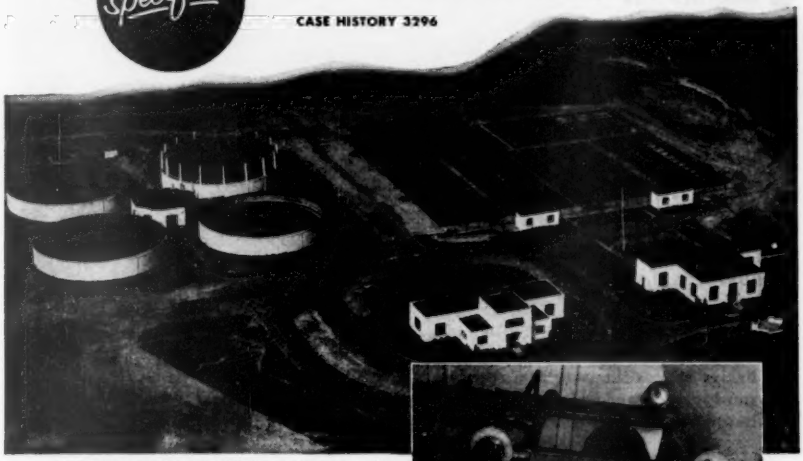
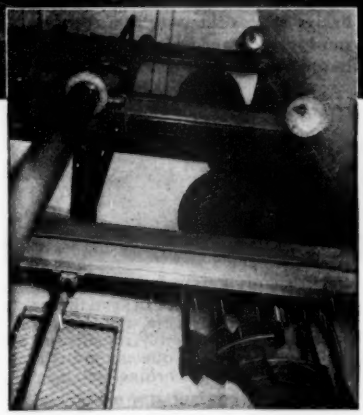
for Portland, Oregon, plants

CASE HISTORY 3296





PORTLAND SEWAGE DISPOSAL PLANT — Durable **Inertol** coatings protect Portland's Sewage Disposal and Treatment System with its 14 pumping stations. Wet wells settling tanks, digesters and submerged concrete take long-lasting **Inertol Standard.** Structure interiors receive **Ramuc Utility;** concrete exteriors get **Ramuc Masonry Paint.** Equipment and nonsubmerged metals are coated with **Glamortex** enamel.

ONE OF 14 PUMPING STATIONS — Glamortex, an alkyd resin enamel, is mar-resistant and long-lasting. **Inertol Standard** cleans easily, speeds flow of sewage. **Ramuc Utility** -- a chlorinated rubber-based enamel — provides a tile-like color-fast finish. Self-cleansing **Ramuc Masonry Paint** will not peel or blister . . . permits concrete to "breathe" . . . stays resistant to chemical action of lime.

In the construction of Portland's new $17,000,000 Sewage Disposal and Treatment System, **INERTOL PAINTS** were selected and specified by the Board of Engineers (Ben S. Morrow, City Engineer) and Portland's Consulting Engineers (Stevens and Koon; John W. Cunningham and Associates). Past satisfactory performance led Stevens and Koon to select **INERTOL** coatings for all 14 pumping stations, since **INERTOL PAINTS** met their precise specifications for hardness, chemical inertness, elasticity, lime and water-resistance.

Using **INERTOL** coatings developed especially for Sewage Plant application, you too can solve your painting problems economically and with full assurance of quality performance. Want *more* information? Then ask to have our Field Technician call. Or write today for our "Painting Guide"—invaluable to Specification Writers, Design Engineers, Plant Superintendents and Contractors. It's *free!*

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Circular Collectors

Types for every waste treatment problem

- DESIGNED FOR EFFICIENT LONG-TERM OPERATION
- ENGINEERED FOR USE IN CIRCULAR OR SQUARE TANKS
- SELECTION OF DRIVES TO MEET YOUR SPECIFICATIONS
- CLARIFLOW THICKENERS FOR FLUE DUST CLARIFICATION

TRACTOR DRIVE COLLECTOR

This pier-supported collector is designed for circular tanks. The rotating bridge acts as the lever arm rotating a sturdy center cage which carries the collector arms. Rotational force is provided by a two-wheeled, rubber tired tractor unit running on the rim (or effluent weir wall of the tank). Drive unit is simple, easily accessible, and not affected by snow or ice.

SUSPENDED COLLECTORS are used where a simple bridge can span the tank diameter. In this case, the complete motor and drive assembly, together with the drive tube and collector arms, are suspended from the bridge.

WRITE FOR BULLETIN 9W65

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This unit utilizes the principles of fluid mechanics, so highly developed in Walker sedimentation units. It removes all settleable solids and remarkably clarifies the flow. All parts are sturdily built... designed for the "tough" jobs.

WRITE FOR BULLETIN 10169

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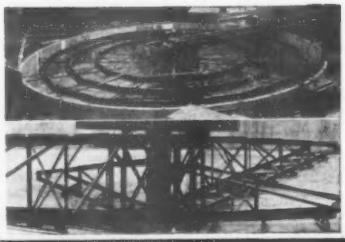
The Pier Drive Collector is recommended where it is undesirable to operate a Tractor Drive... where the access bridge must be stationary, or the corners of square tanks must be scraped. Center drive mechanisms, ranging from 1/2 to 10 horsepower, are built for long life and heavy duty service. Worms are carburized and ground steel and precision meshed with hardened bronze worm wheels. The balls run in hardened, ground, renewable ball races.



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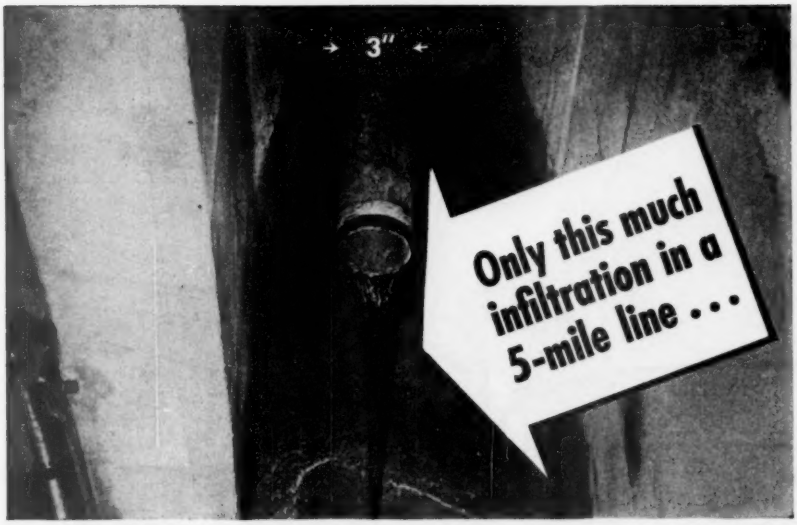


. . . with Transite Sewer Pipe and its "*packaged*" RING-TITE JOINT

The photograph above shows the total amount of infiltration—through manholes as well as pipe—in a recently installed sewer system consisting of 5 miles of 6", 8", 12" and 18" diameter Transite Sewer Pipe. So little ground water entered the system that the only practical way it could be measured was by inserting a 3" pipe in the Parshall flume as shown here!

Here is visual proof that Transite Sewer Pipe with its Ring-Tite Joint cuts ground water infiltration to a minimum—in this case less than 3.4% of the specified allowable of 600 gallons per inch of pipe diameter, per mile, per day.

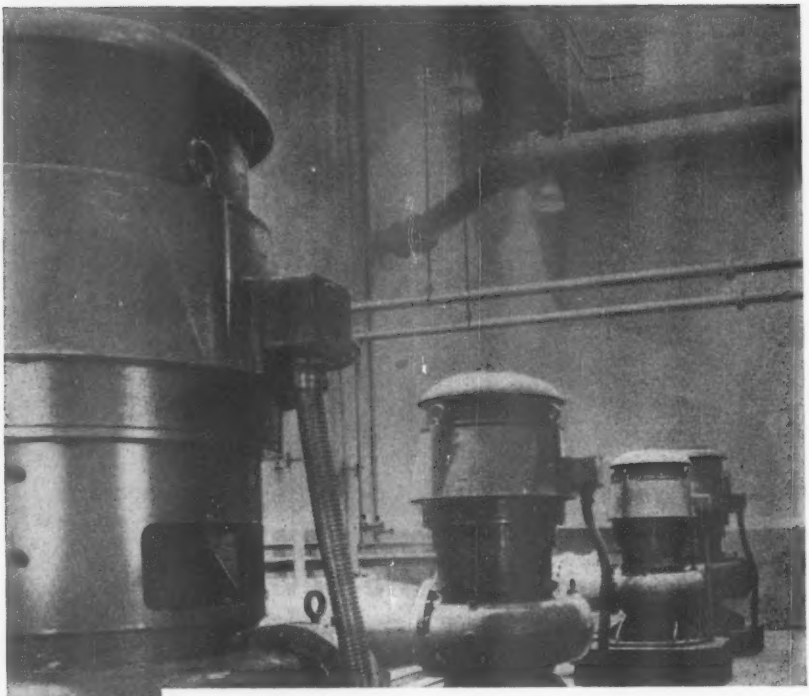
The Ring-Tite Joint, standard on all sizes of Transite Sewer Pipe, has other important practical advantages, too. Actually a factory-made joint, it can be assembled in a fraction of the time required for making ordinary sewer pipe joints. No jointing compounds are used—just a simple assembly operation with a mechanical coupling puller does the job. And you can check each joint for proper assembly as soon as it is made—*and backfill immediately!*

Transite Sewer Pipe may also help you save in other ways. Its long 13-foot lengths mean *fewer* joints to make—thus further reducing installation expense. And its high flow capacity (Manning's n=.010.) often permits flatter grades and shallower trenches—a particularly important economy where pipe is laid at or below the ground water line or where rock excavation is required.

For more facts about this money-saving asbestos-cement pipe, write for Folder TR-103A. Address Johns-Manville, Box 60, New York 16, N. Y.

*Transite is a registered Johns-Manville trade mark

Johns-Manville TRANSITE SEWER PIPE



Keep This Angle in Mind

. . . that when you want to move big volumes of sewage or storm water *economically,* your best bet is Fairbanks-Morse *Angle*flow Pumps. Designed for maximum plant efficiencies where large quantities must be pumped against moderate heads, these dependable pumps give you a new high in service . . . a new low in operating and maintenance costs. Wide, unobstructed passages through impeller and volute make them especially suitable for handling debris-filled water. Sizes range from 8 to 54 inches . . . capacities up to 80,000 g.p.m. For complete information see your local Fairbanks-Morse Branch or write Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago 5, Ill.

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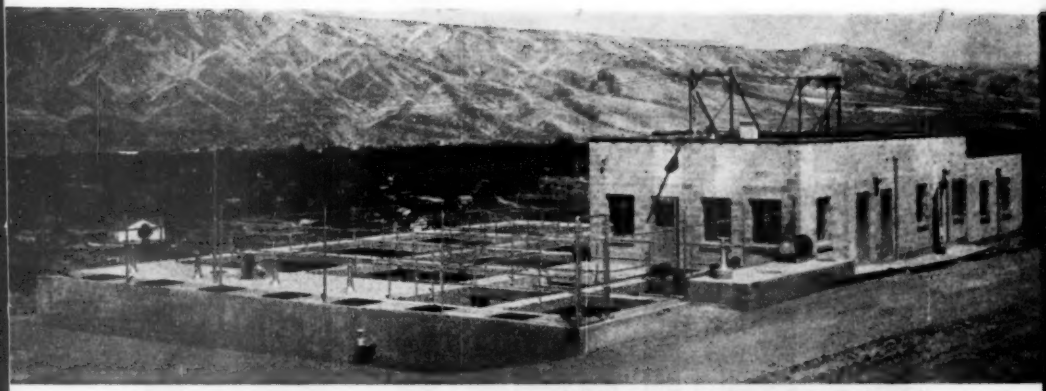
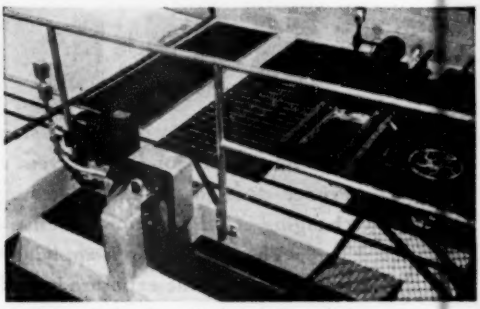


Washington Water Power Co.'s Clarkston filtration plant gets water from 19,000,000 gal. reservoir. Consulting engineer: W. L. Malony, Spokane, Wash.

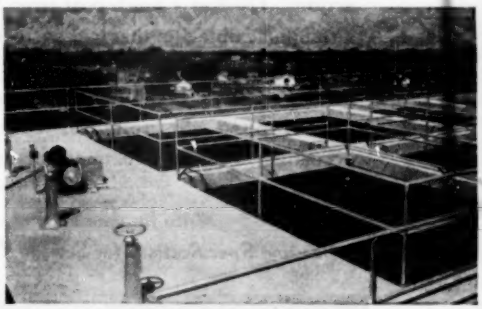
LINK-BELT supplies major equipment for Clarkston, Wash., filtration, sewage plants

CITIZENS of Clarkston, Wash., received a healthy boost in sanitary services recently. Their new water filtration plant, equipped with Link-Belt mixers and collectors, purifies water at an average rate of 3 mgd. In addition, major equipment in the new sewage plant was also built by Link-Belt.

The Link-Belt collectors of the Straightline type and Link-Belt mixers provide optimum flocculation and maximum sludge collection and removal in the shortest time. Economical operation is assured at all flow conditions. Whether your requirements are large or small, our sanitary engineers will be glad to work with your engineers, chemists and consultants—help you get the best in modern water, sewage or industrial liquids treatment.



Link-Belt flash mixer (background) and slow mixer are driven through Link-Belt worm gear and motorized P.I.V. variable speed drive with Class 700 Pintle chain, respectively. Each performs thorough mixing action required.



Water flows from flocculation tanks to two-compartment, 38 x 70 ft. settling tank, containing Straightline Sludge Collectors. Both are operated by the single Link-Belt 1-hp motorized worm gear drive.

At Clarkston's new sewage treatment plant, two Link-Belt Straightline Sludge Collectors, plus a mechanically cleaned bar screen, efficiently remove the solids from the sewage. Consulting engineer: R. H. Corey, Portland, Ore.

LINK-BELT COMPANY: Plants—Chicago, Indianapolis, Philadelphia, Atlanta, Houston, Minneapolis, San Francisco, Los Angeles, Seattle, Toronto, Springs (South Africa), Sydney (Australia). Sales Offices in Principal Cities.

12.97

LINK-BELT

SANITARY ENGINEERING EQUIPMENT

TNEMEC PRIMERS KILL RUST!

THE first step in preserving steel with paint is applying the prime coat. Its primary job is to prevent and kill rust action. TNEMEC 99 Metal Primer does just that, by creating a neutral condition on steel surfaces, changing active rust and corrosive agents into an inactive neutral compound.

The second step is applying the finish coat that will provide protection against the specific exposure hazards involved.

SEWAGE ATMOSPHERE IS CORROSIVE!

. . . and 457 TNEMECOL is your best protection against its disintegrating action. Used as a finish coat over TNEMEC 99 Primer, TNEMECOL forms a tough, flexible film that makes steel surfaces immune to sludge and its gases.

Try this team on your next job—TNEMEC 99 Primer and 457 TNEMECOL—the combination that has whipped the toughest corrosion problems occurring in sewage treatment plants.

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Painting Specifications for Sewage Treatment Plants

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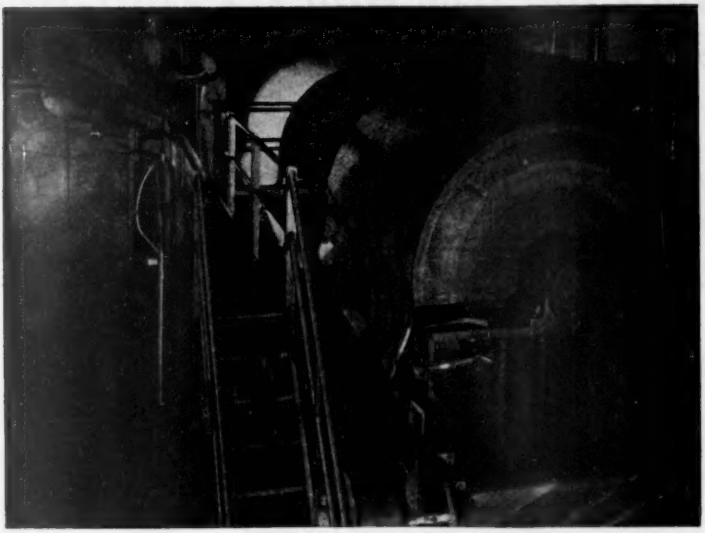


Two Eimco Filters in Sewage Plant, Waterbury, Conn. Plant construction directed by H. C. Whitlock, supervised by W. N. Kunsch.

NEW SEWAGE PLANT DEWATERS SLUDGE

—and **Everdur** is chosen for the Eimco Vacuum Filters that do the job

MALCOLM PIRNIE, consulting engineer of New York, designed the sewage plant for Waterbury, Conn. to treat domestic sewage mixed with industrial waste. Vacuum filtration and incineration were advised.

Eimco Corp. supplied two continuous rotary filters with swing agitators. Everdur* was chosen to resist the corrosive sludge effluent. All woven wire screens (5 x 5 mesh x .063" gage), division strips, bolts, nails and screws are Everdur.

Strength, corrosion resistance, good working and welding properties recommend Everdur as a durable alloy. In handling industrial wastes, corrosion problems are complicated. For the proper Everdur Alloy for your application write our Technical Department. The American Brass Co., Waterbury 20, Conn. In Canada: Anaconda American Brass Ltd., New Toronto, Ont. 53150A

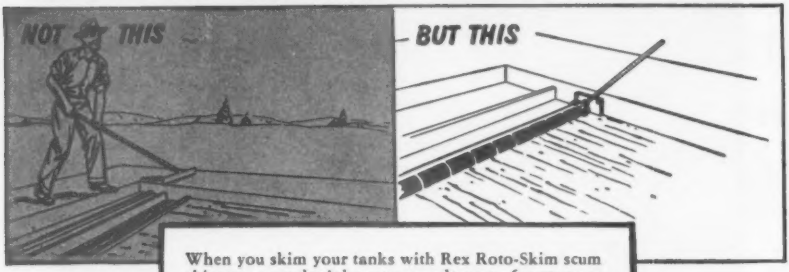
*Reg. U. S. Pat. Off.

specify **EVERDUR**

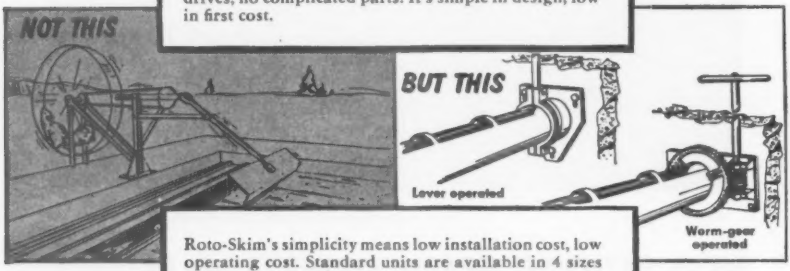
ANACONDA®
COPPER SILICON ALLOYS

Strong
Weldable
Workable
Corrosion-Resistant

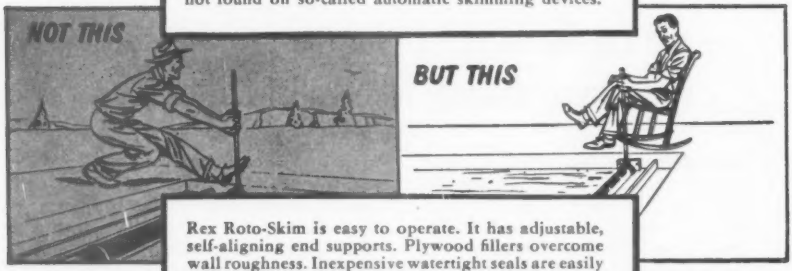
WHEN YOU SKIM WITH REX ROTO-SKIM



When you skim your tanks with Rex Roto-Skim scum skimmers you don't have to spend money for concrete scum troughs. With Roto-Skim there's no raking, no drives, no complicated parts. It's simple in design, low in first cost.



Roto-Skim's simplicity means low installation cost, low operating cost. Standard units are available in 4 sizes and are delivered completely assembled. It can be adjusted for fluctuations in water level . . . a feature not found on so-called automatic skimming devices.



Rex Roto-Skim is easy to operate. It has adjustable, self-aligning end supports. Plywood fillers overcome wall roughness. Inexpensive watertight seals are easily renewable. There is no power . . . no greasing . . . no stuffing box seal.

For complete details, call your nearest Rex Sanitation engineer or write for Bulletin 51-83, Chain Belt Company, 4606 W. Greenfield Avenue, Milwaukee 1, Wisconsin.

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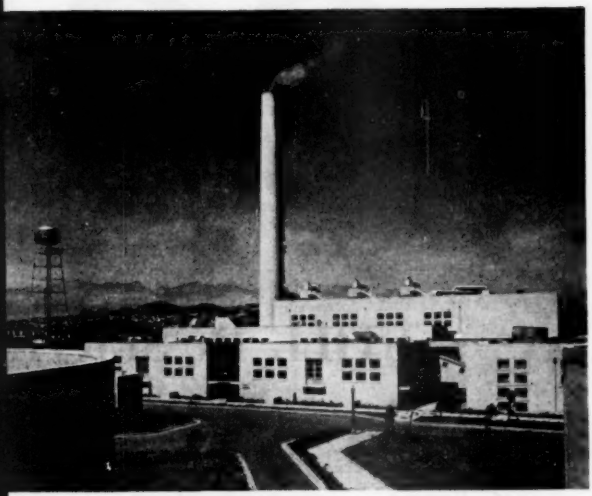
New North Point sludge treatment plant

San Francisco, California



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Fond du Lac, Wis.	Jerry Donohue Engrg. Co.
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Lansing, Mich.	Drury, McNamee and Porter
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San Diego, Cal.	Frank Currie
San Francisco, Cal.	Clyde C. Kennedy
Schenectady, N. Y.	Havens and Emerson
Sheboygan, Wis.	Jerry Donohue Engrg. Co.
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York, Pa.	Albright & Friel

Industrial sludges a problem?

C-E Raymond Flash Drying and Incineration Systems have been the answer for others. Write for information.

California growers now have a valuable new source of fertilizer — San Francisco's large new North Point Sludge Treatment Plant.

In this plant, three C-E Raymond Flash Drying Units are geared to produce about 100 tons of high-grade, marketable fertilizer every day. This is equivalent to an evaporation rate of 18,750 pounds of water per hour from the filter cake that enters the flash drying units.

The North Point plant serves an equivalent population of 1,400,000 in the San Francisco area. It is typical of C-E Raymond System installations throughout the country, serving the needs of both large and small communities. These installations are flexible, efficient and reliable; they provide for maximum utilization of waste heat.

To see how they can serve your community, too, get in touch with the C-E office nearest you. A flash dryer specialist will be glad to help you find the best solution to your sludge disposal problem.

B-614A

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STILL IN SERVICE

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The survey shows that 96% of all the cast iron water mains ever laid by 25 representative cities in sizes 6-inch and larger *are still in service.*

A detailed report of the survey has recently been published by the American Water Works Association. We have reprinted, by permission, the facts pertaining to cast iron water mains in a brochure which will be sent on request. Write to Cast Iron Pipe Research Association, Thomas F. Wolfe, Managing Director, 122 South Michigan Ave., Chicago 3, Ill.

CAST IRON

CAST IRON PIPE SERVES FOR CENTURIES

SEWAGE AND INDUSTRIAL WASTES

Journal of the Federation of Sewage and Industrial Wastes Associations

Volume 24 **October, 1952** **Number 10**

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W. H. Wisely, *Editor*, 325 Illinois Building, Champaign, Illinois

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Complete Elimination of Scum...
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Sewage Works

CORROSION STUDIES AND THE USE OF STAINLESS STEEL AT THE BACK RIVER SEWAGE TREATMENT WORKS, BALTIMORE, MD.

By C. E. Keefer and Kenneth M. Huston

Deputy Sewerage Engineer, Bureau of Sewers, and Senior Research Engineer, Armco Steel Corporation, respectively, Baltimore, Md.

One of the problems at many sewage treatment works relates to the corrosion of ferrous and non-ferrous metals. Both of these types of metals are used for a wide variety of purposes. Ferrous metals are used in sludge removal equipment, settling tanks, rotary distributors on trickling filters, conveying equipment, pipe lines, valves, sluice gates, and many other types of apparatus. Non-ferrous metals such as aluminum, copper, and bronze are used for numerous purposes where more corrosion-resistant properties are required.

There are several reasons for the corrosion of metals being especially severe at sewage plants. Sewage generally contains greases and fats that frequently accumulate on metal surfaces at the water line in tanks containing sewage. These materials decompose with the production of fatty acids that attack metal surfaces. Furthermore, hydrogen sulfide is often produced by septic sewage. This gas is very corrosive to copper. In the presence of moisture and air it is oxidized to sulfurous and then to sulfuric acid. Ferrous metals are particularly susceptible to corrosion in the presence of this acid. Chlorine, which is used extensively at sewage plants, is quite corrosive to almost all metals in the presence of moisture. Ferric chloride and chlorinated copperas, widely used to coagulate sewage sludge, are excellent oxidizing agents and consequently disintegrate many metals. The high moisture content in the atmosphere at many sewage plants, particularly where trickling filters are used and where screens, channels, and tanks are enclosed in buildings, is also conducive to corrosion.

At the Back River sewage treatment works serving Baltimore, Md., many corrosion problems have been encountered during the past 40 years of plant operation. Copper gutters and rain leaders on buildings, and copper screens in windows, have deteriorated in a few years and have had to be replaced. Window screens made of bronze and aluminum have also proved unsatisfactory. Copper piping and bronze fittings inside vacuum filters deteriorated in one instance in about two years. This deterioration was attributed to the oxidation of the copper by ferric ions in the filtrate. Steel lamp posts and steel gratings on the trickling filters were very badly corroded in less than 10 years. Bronze wire used to hold filter cloths on vacuum filters had to be replaced after 1,600 hr. of service. These are some of the more pronounced examples of corrosion.

Description of Corrosion Tests

To solve some of these problems, the research laboratories of Armco Steel Corporation, with the cooperation of the Baltimore Bureau of Sewers, conducted an extensive series of tests at

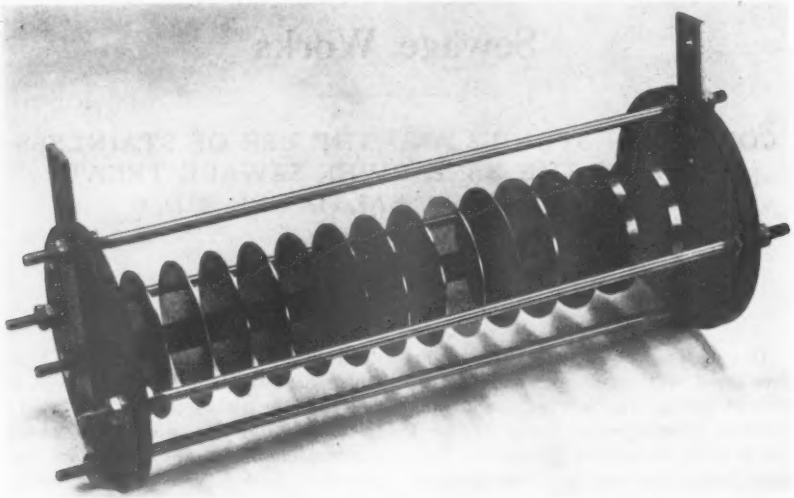

FIGURE 1.—Spool-type specimen holder assembled with round specimens.

the Back River sewage treatment works. These tests covered a period of four years and were made in the revolving screen building, the sludge control station, and the vacuum filter building. The corrosion of metals in these three buildings has been quite severe. In the revolving screen building five drum-type, rotary, fine screens, which treat settled sewage prior to its being applied to trickling filters, are cleaned by jets of settled sewage impinging on the outer surfaces of the screens as they revolve. The spray

TABLE I.—Typical Chemical Composition of Metals Exposed at the Back River Sewage Treatment Works

(Amount expressed in percentages)

Material	C	Mn	P	S	Si	Cr	Ni	Mo	Cu	Ti	Al	Cb	Fe	Mg	Zn	Slag
Stainless steel:																
Type 304	0.07	1.0	0.02	0.02	0.5	19.0	8.0	—	0.2	—	—	—	[1]	—	—	—
Type 316	0.07	2.0	0.03	0.02	0.5	17.6	13.1	2.4	0.3	—	—	—	[1]	—	—	—
Type 317	0.07	1.7	0.03	0.01	0.5	18.1	13.4	3.1	0.2	—	—	—	[1]	—	—	—
Armco 17-14 Cu-Mo	0.09	0.8	0.03	0.01	0.5	16.0	14.3	2.4	3.0	0.7	—	0.3	[1]	—	—	—
Armco 17-7 PH	0.07	0.6	0.02	0.01	0.5	16.9	7.0	—	0.3	—	1.1	—	[1]	—	—	—
Armco 17-4 PH	0.07	0.6	0.02	0.02	0.4	16.3	4.5	—	3.8	0.3	—	—	[1]	—	—	—
Type 410	0.10	0.5	0.02	0.02	0.3	12.6	0.3	0.5	—	—	—	—	[1]	—	—	—
Type 416	0.10	0.6	0.02	0.30	0.4	12.7	0.4	0.4	—	—	—	—	[1]	—	—	—
Type 430	0.07	0.5	0.02	0.02	0.5	17.0	0.4	—	—	—	—	—	[1]	—	—	—
Type 430F	0.07	0.7	0.02	0.30	0.4	16.3	0.7	—	—	—	—	—	[1]	—	—	—
Type 431	0.13	0.5	0.02	0.02	0.4	16.4	1.3	—	—	—	—	—	[1]	—	—	—
Aluminum:																
17 ST	—	0.7	—	—	0.8	—	—		4.0	—	[1]	—	1.0	0.5	0.1	—
Nickel alloys:																
Monel	0.15	1.0	—	—	0.1	—	67.0	—	30.0	—	—	—	1.4	—	—	—
Inconel	0.08	0.2	—	—	0.2	14.0	78.5	—	0.2	—	—	—	6.5	—	—	—
Copper	—	—	—	—	—	—	—	—	99.9	—	—	—	—	—	—	—
Iron and steel:																
Cor Ten	0.10	0.2	—	—	0.7	1.0	—	—	0.4	—	—	—	[1]	—	—	—
Mild killed	0.15	0.4	0.03	0.03	0.2	—	—	—	—	—	—	—	[1]	—	—	—
Mayari R	—	—	—	—	—	0.6	1.2	—	—	—	—	—	[1]	—	—	—
Wrought iron	0.08	0.02	0.06	0.01	0.16	—	—	—	—	—	—	—	[1]	—	—	1.2

[1] Remainder.

from these jets produces a very humid atmosphere in the building, which conduces corrosion. The south wing of the sludge control station contains two adjacent pits, into which raw and digested sludge discharge many hours each day. The moisture given off by the sludge permeates the atmosphere above the sludge pits and is quite corrosive. The third location where corrosion is prevalent is in the chlorinating room of the vaccum filter building, where ferrous sulfate is chlorinated. At times chlorine escapes and corrodes practically all metals with which it comes in contact.

In one group of tests duplicate sets of spool-type specimens similar to those described in "Recommended Practice for Conducting Plant Corrosion Tests" (A.S.T.M. Designation: A224–46) were exposed in the revolving screen building, the sludge control station, and the chlorinating room of the vacuum filter building for 6 and 18 months. The spool-type specimen holders (Figure 1) were designed to (a) prevent the

TABLE II.—Heat Treatment Given Stainless-Steel Samples Exposed at Back River Sewage Treatment Works

Sample Type	Annealing or Hardening		
	Temp. (° F.)	Time (hr.)	Quench
(a) Annealed Samples			
304	1,950	0.5	Water
316	2,050	0.5	Water
317	2,050	0.5	Water
Armco 17–14 Cu-Mo	2,050	0.5	Water
430	1,475	0.5	Water
430F	1,475	0.5	Water
(b) Cold-Drawn and Hardened Samples			
Armco 17–4 PH [1]	900	1	Air
Armco 17–7 PH [1]	850	4	Air
(c) Hardened and Stress-Relieved Samples			
410 [2]	1,800	0.5	Oil
416 [2]	1,800	0.5	Oil
431 [2]	1,900	0.5	Oil

[1] Hardened after being cold-drawn.
[2] Hardened as shown, then stress-relieved for 2 hr. at 500° F. and air-quenched.

TABLE III.—Corrosion Tests of Various Metals in Revolving Screen Building

Sample	Corrosion Rate (in./yr.)[1]		Appearance After 18 Months
	After 6 Months	After 18 Months	
Stainless steel:			
AISI 410	0.0000	0.0000	Bright
AISI 430	0.0000	0.0000	Bright
AISI 304	0.0000	0.0000	Bright
AISI 316	0.0000	0.0000	Bright
Aluminum:			
17 ST	0.0001	0.0000	Dull
Nickel alloys:			
Monel	0.0001	0.0001	Light over-all etch, few shallow pits
Inconel	0.0000	0.0000	Bright, few scattered shallow pits
Copper	0.0010	0.0003	General etch, many scattered shallow pits
Iron and steel:			
Wrought iron	0.0010	0.0007	Over-all etch and shallow pitting
Mild killed	0.0010	0.0007	Over-all etch and shallow pitting
Mayari R	0.0001	0.0008	Over-all etch and shallow pitting
Cor Ten	0.0010	0.0007	Over-all etch and shallow pitting

[1] Inches of penetration per year.

TABLE IV.—Corrosion Tests of Various Metals in Sludge Control Station

Sample	Corrosion Rate (in./yr.)[1]		Appearance After 18 Months
	After 6 Months	After 18 Months	
Stainless steel:			
AISI 410	0.0005	0.0002	Heavy etching in localized areas
AISI 430	0.0000	0.0000	Bright
AISI 304	0.0000	0.0000	Bright
AISI 316	0.0000	0.0000	Bright
Aluminum:			
17 ST	0.0001	0.0001	Lightly etched
Nickel alloys:			
Monel	0.0001	0.0004	Light over-all etch, many shallow pits
Inconel	0.0000	0.0000	Bright, few scattered shallow pits
Copper	0.0018	0.0021	Rough, shallow pits over-all
Iron and steel:			
Wrought iron	0.0020	0.0037	Severe etch, deep pits over-all
Mild killed	0.0020	0.0029	Over-all severe etch and shallow pitting
Mayari R	0.0024	0.0032	Over-all severe etch and shallow pitting
Cor Ten	0.0020	0.0022	Over-all severe etch and shallow pitting

[1] Inches of penetration per year.

TABLE V.—Corrosion Tests of Various Metals in Chlorinating Room of Vacuum Filter Building

Sample	Corrosion Rate (in./yr.)[1]		Appearance After 18 Months
	After 6 Months	After 18 Months	
Stainless steel:			
AISI 410	0.0024	0.0025	Severely etched, shallow pits over-all
AISI 430	0.0001	0.0012	Severely etched, shallow pits over-all
AISI 304	0.0002	0.0008	Severe over-all etch, deep pits, perforations
AISI 316	0.0000	0.0007	Severe over-all etch, deep pits, perforations
Aluminum:			
17 ST	0.0003	0.0009	Dark, severely etched
Nickel alloys:			
Monel	0.0003	0.0011	Rough, etched over-all
Inconel	0.0001	0.0002	General etch, many large shallow pits
Copper	0.0003	0.0010	Slightly rough, few shallow pits
Iron and steel:			
Wrought iron	0.0023	0.0049	Severe etch, deep pits over-all
Mild killed	0.0023	0.0049	Over-all severe etch and shallow pitting, many scattered deep pits
Mayari R	0.0026	0.0039	Severe etch and shallow pits over-all
Cor Ten	0.0026	0.0029	Severe etch and shallow pits over-all

[1] Inches of penetration per year.

loss of specimens from causes other than corrosion, (b) eliminate any possibility of galvanic effects resulting from metal-to-metal contact between specimens or between the vessel and the specimens, (c) hold the specimens firmly in place, and (d) provide for the protection of the specimens against mechanical damage. Table I gives the typical chemical analyses of the samples that were tested; Table II indicates the heat treatment given these samples. Corrosion rates and appearance evaluation as determined by these samples are shown in Tables III, IV, and V. An analysis of the products of corrosion indicated that corrosion is caused by chlorine or chlorides and apparently does not result from sulfur compounds. Of the alloys tested, the stainless-steel alloys, 17ST aluminum, Monel, and Inconel are best suited for atmospheric applications in the revolving screen building and the sludge control station.

In the chlorinating room of the vacuum filter building, however, even though the corrosion rate of AISI * Types 304 and 316 stainless steel and Inconel was insignificant, the pitting attack precludes the use of these alloys. Although the aluminum alloy did not pit, the rate of corrosion was higher than that observed for Types 304 and 316 stainless steel and Inconel. Another significant observation was the accumulation of a slimy coating on the samples in the chlorinating room of the vacuum filter building between 6 and 18 months of exposure. This coating

* American Iron and Steel Institute designations.

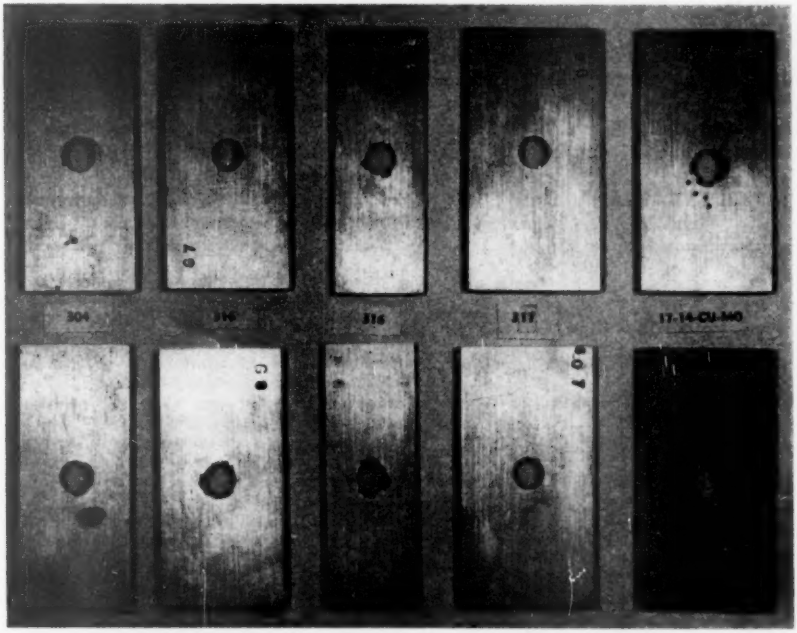

FIGURE 2.—Stainless-steel specimens exposed for 31 months to sludge coagulated with chlorinated copperas.

(All samples in Figures 2 and 3 showed some degree of contact corrosion, which is characteristic of insulator-stainless steel joints of this type.)

TABLE VI.—Corrosion Tests of Stainless Steel in Vacuum Filter Tank
(Samples immersed in sludge coagulated with chlorinated copperas)

Sample	Corrosion Rate (in./yr.)[1]		Appearance After 31 Months
	After 12 Months	After 31 Months	
Stainless steel:			
AISI 304	0.0005	0.0001	Few deep pits in localized areas, otherwise no attack; deepest pit 0.076 in.
AISI 316	0.0000	0.0000	Very few very shallow pits; deepest pit 0.0001 in.
AISI 316, welded	0.0000	0.0004	Same as Type 316; no attack at weld; deepest pit 0.005 in.
AISI 317	0.0000	0.0000	No attack
Armco 17–14 Cu-Mo	0.0000	0.0000	No attack

[1] Inches of penetration per year.

was not observed when the first group of samples was removed. Analysis of the products of corrosion from the samples indicated the presence of iron, oxides, and chlorides, with a trace of sulfate.

In a second group of tests in the vacuum filter building duplicate sets of spool-type stainless-steel specimens were exposed on the agitator arm in a vacuum filter tank, which contained digested sludge coagulated with chlorinated copperas. Figure 2 indicates the extent of corrosion after 31 months, and Table VI gives the corrosion rates after 12 and 31 months of exposure. Another duplicate set of specimens was attached to a support beneath a belt conveyor removing the dewatered sludge from the vacuum filters. Figure 3 shows the appearance of these specimens at the end of 31 months, and Table VII gives the corrosion rates after 12 and 31 months of exposure. Of

TABLE VII.—Corrosion Tests of Stainless Steel under Dewatered-Sludge Belt Conveyor
(Samples of steel frequently exposed to spillage of vacuum filter sludge cake)

Sample	Corrosion Rate (in./yr.)[1]		Appearance After 31 Months
	After 12 Months	After 31 Months	
AISI 410	0.0000	0.0001	Generally pitted, with one or two large pitted areas on each sample; deepest pit 0.064 in.
AISI 416	0.0001	0.0002	More generally pitted than Type 410; no large pitted areas; deepest pit 0.099 in.
AISI 430	0.0000	0.0002	More extensively pitted than Type 416; several large pitted areas; deepest pit 0.058 in.
AISI 430F	0.0001	0.0004	Generally etched and severe shallow pitting over all areas; deepest pit 0.025 in.
AISI 431	0.0000	0.0001	Better than Type 410; pitting not so general, but one or two large pitted areas on each sample; deepest pit 0.075 in.
Armco 17–4 PH	0.0001	0.0001	Better than Type 430; general shallow pitting over all areas; deepest pit 0.063 in.
Armco 17–7 PH	0.0000	0.0000	Few scattered shallow pits; better than Armco 17–4 PH; deepest pit 0.008 in.
AISI 304	0.0000	0.0000	Very shallow localized pits, some in clusters; deepest pit 0.021 in.

[1] Inches of penetration per year.

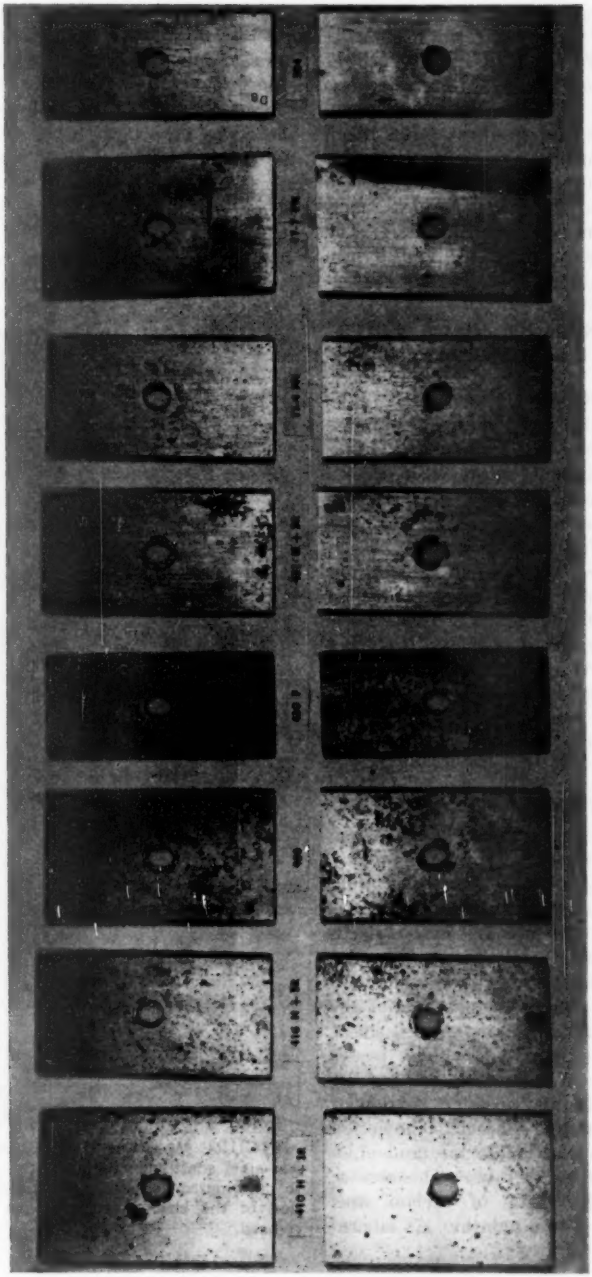

FIGURE 3.—Stainless-steel specimens exposed to spillage of vacuum filter cake for 31 months.

the samples exposed in the vacuum filter tank, the best results after 31 months were obtained with Type 317 and Armco 17–14 Cu-Mo stainless steels. The next best results were obtained with Type 316 stainless steel. Of the specimens exposed under the dewatered sludge belt conveyor, Armco 17–7PH and Type 304 stainless steels were most resistant to corrosion. The next best were Type 431 and Armco 17–4PH stainless steels.

Plant-Scale Experience with Stainless Steel

Primary Settling Tanks

During the past 16 years stainless steel has been used at the Back River sewage treatment works with considerable success in several places where corrosion has been excessive. Stainless steel was first used in 1936 in ¾-in. bolts for securing railroad rails on top of the walls of two mechanically-cleaned primary settling tanks. These bolts replaced carbon-steel bolts that had been in service about one year. The new bolts, made of Type 410 stainless steel, have been in service for about 16 years and are still in excellent condition.

Ferrous Sulfate Chlorinating Tank

Another severe corrosion problem has been adjacent to the stuffing box on the top of a rubber-lined steel tank, in which dissolved ferrous sulfate is chlorinated. A motor-driven steel shaft, which passes through this stuffing box, has attached to its lower end two paddles for mixing the contents of the tank. The paddles and the steel shaft, except that portion which passes through the stuffing box, are rubber coated. It is this uncoated portion of the shaft which is subject to the action of ferrous sulfate, chlorine, and chlorinated ferrous sulfate. The service life of shafts made of carbon steel varied from 3 to 6 months. As laboratory tests indicated that Armco 17–14 Cu-Mo stainless steel has good resistance to low concentrations of hydrochloric acid, this material was used in the shaft. After two months of service there was no attack in the vicinity of the stuffing box, but there was severe attack below the surface of the solution (Figure 4). As an emergency repair, the Armco 17–14 Cu-Mo shaft in the vicinity of the stuffing box was used to replace a section of another rubber-

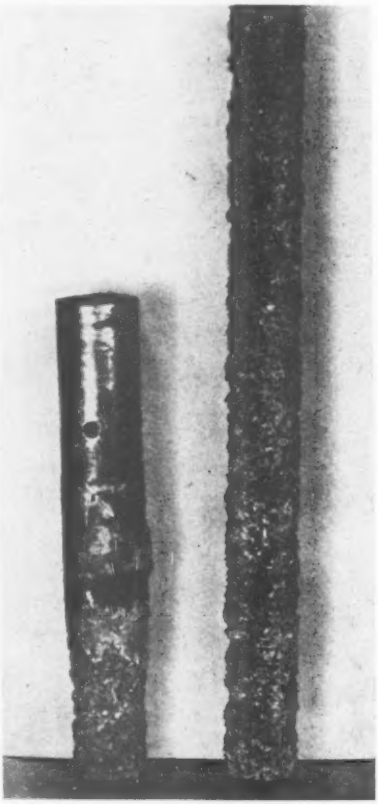

FIGURE 4.—Armco 17–14 Cu–Mo stainless-steel shaft after two months exposure to chlorinated copperas. The shorter section of the shaft (left) was cut off and re-used.

covered shaft that had badly corroded at the stuffing box. After eight months of service this emergency shaft showed no signs of corrosion in the vicinity of the stuffing box. This shaft was replaced by an Armco 17–14 Cu-Mo stainless-steel shaft which was rubber coated except in the vicinity of the stuffing box. After two years of service this shaft failed as a result of acidulated ferric chloride corrosion due to overfilling the tank.

Screen for Ferrous Sulfate

A recent application of stainless steel at the Back River plant has been the use of Type 317 in a perforated metal screen at the outlet of a tank into which ferrous sulfate salt is dumped and then dissolved. The function of the screen, through which the ferrous sulfate solution flows, is to hold back any foreign matter. It is anticipated that this screen will provide many years of maintenance-free service.

Crevice Corrosion and Corrosion Barriers

The installation of the above-mentioned screen illustrates another procedure necessary to insure trouble-free maintenance of stainless-steel equipment. The screen is supported on a wooden frame, which could cause failure by contact corrosion (crevice corrosion, deposit attack, or cranny corrosion) in a relatively short time if the frame were permitted to come in direct contact with the stainless steel. This type of attack may occur where two materials, one of which may be a non-conductor of electricity, are joined so that a crevice is left between them. Anaerobic conditions may result when the crevice is filled with a salt solution or even with fresh water, or a concentration cell may result, which would break down the normally passive film of the stainless steel and result in a localized attack at the crevice. This type of corrosion may be minimized by coating the contacting surface with a corrosion barrier.

This barrier may be any non-corrosive material which will adhere to the stainless-steel surface. This surface presents a unique phenomenon in that a normally passive transparent film serves to retard corrosive action. However, this film presents a problem in obtaining satisfactory adhesion of corrosion barriers to the surface. Arco zinc chromate primer No. 214–30089 or sealer No. EC870 as made by the Minnesota Mining and Manufacturing Company provides satisfactory adhesion and serves as a good corrosion barrier. The wood-stainless-steel contacting surfaces of the copperas screen were coated with Arco zinc chromate primer.

Downspouts and Gutters

When the Back River sewage treatment plant was put in service in 1911, the gutters and downspouts on the administration building were made of copper. This metal corroded quite rapidly, presumably as a result of hydrogen sulfide attack. The gutters and downspouts have now been replaced with 18–8 stainless steel, which should offer good corrosion resistance.

After 24 months of exposure, rust streaks have appeared on the downspouts. These have no significant effect on the corrosion resistance, but do mar the appearance. Swabbing a 50 per cent solution of Oakite 33 over the surface will dissolve the rust and leave it free of rust stains. Excess solution may be removed by the next rainfall; or when indoors, by rinsing with water the next day.

Centrifugal Sludge Pump

In certain instances at the Back River plant the bronze or steel sleeves on the shafts of centrifugal sludge pumps adjacent to the packing glands wear quite rapidly due to abrasion. Type 410 stainless-steel sleeves with a

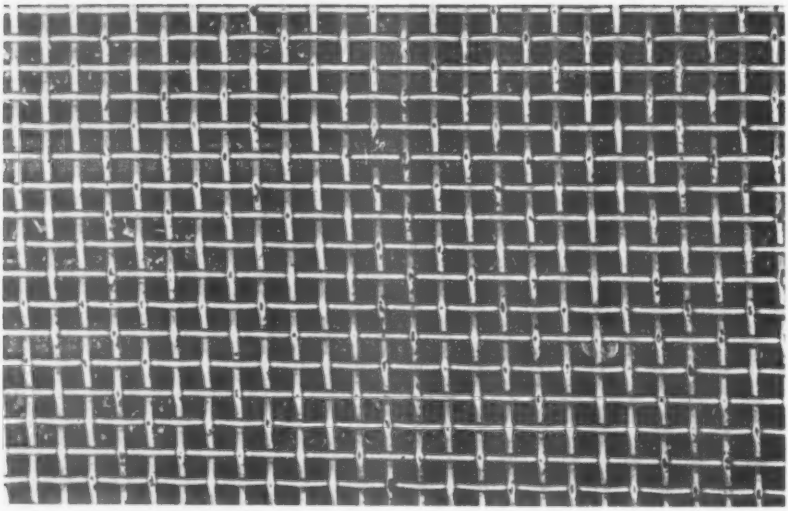

FIGURE 5.—Type 317 stainless-steel screen support for cloth on vacuum filter after 15,000 hr. of service.

hardness of Rockwell C37–40, nitrided to a hardness of Rockwell C65–70, are being tried for this service. This greater hardness should reduce maintenance considerably.

Vacuum Filters

Another successful application of stainless steel has been its use in vacuum filters; first, in the screens supporting the filter cloths, and secondly as a wire winding for holding the cloths on the filters. When the filters were purchased, the screen supports under the filter cloths were made of Monel. This material had a life of five years. In Feb., 1949, Type 317 stainless-steel wire cloth was used in place of Monel wire. This wire (Figure 5) was examined in Feb., 1952, and was in very good condition.

As has been previously noted, the phospher bronze wire used to hold the filter cloths in place had a service life of about 1,600 hr. In Feb., 1949, Type 317 stainless-steel wire was substituted for the bronze wire. As of March, 1952, the wire was in good condition.

Effect of Mechanical Properties

An interesting problem arose in connection with wrapping the wire around the filter cloths. It was reported that although stainless-steel wire was more difficult to cut than bronze wire, it was softer and had a greater tendency to come loose during the operation of the filters. A laboratory examination of the strength of the bronze and the stainless-steel wires produced the following information:

	Bronze	Type 317 Stainless Steel
Ult. tensile strength (lb./sq. in.)	85,000	105,000
Yield strength (lb./sq. in.)	80,000	40,000

These data indicated that the stainless-steel wire was in the annealed condition and as such was less resistant to stretching than bronze wire. Cold-drawing the wire to an ultimate tensile strength of 115,000 to 135,000 lb. per sq. in. produced a wire with a yield strength of 80,000 lb. per sq. in., which was satisfactory for the application.

Technical Assistance for Engineers

In this connection it is well to know that heat treatment or cold working of stainless steels has an important bearing on their mechanical properties and corrosion resistance. The designing engineer should consult with stainless-steel technicians before attempting to solve corrosion problems by using stainless steel. They are familiar with grades, heat treatments, and corrosion resistance of stainless steels and can furnish information regarding the selection of the proper grade of steel to assure long life and economies in maintenance.

The foregoing discussion indicates that stainless steel is finding an ever-widening field of application at the Back River sewage treatment works.

Applications for Stainless Steel

There is a definite trend toward the wider use of corrosion-resisting materials at sewage treatment works, particularly for those vital parts of equipment where corrosion of ordinary material would seriously impair efficiencies and cause the frequent suspension of operation for repairs. It is interesting to note that stainless steels have been used in such applications as underwater parts of circular clarifiers, fire hydrant valve rods, expansion joints, sewage pipe connecting bolts and nuts, comminutors, and sleeves on centrifugal pump shafts.

Other probable applications include:

1. Coarse screening:
   a. Bolts and nuts for assembling mechanical bar-screen cleaners.
   b. Pintles on chain belts for bar-screen cleaners.
2. Grit chambers:
   a. Sluice gates and their controlling mechanisms.
   b. Bolts and nuts for assembling detritors.
3. Fine screening:
   Wire cloth (Type 316) for drum-type screens.
4. Concrete tanks:
   a. Expansion joints.
   b. Bolts and nuts and small moving parts in clarifiers.
   c. Pintles on chain sludge collectors.
5. Activated sludge process:
   Air piping to aeration tanks.
6. Sludge handling:
   a. Backing wire (Type 317) and gutter strips on continuous vacuum-type filters.
   b. Conveyor worms.
7. Miscellaneous:
   a. Piston rods on reciprocating pumps and sleeves on the shafts of centrifugal pumps.
   b. Valve stems on gate valves and sluice gates.
   c. Pins in bucket elevator chains.
   d. Sewage meter parts.
   e. Cooling towers.

Conclusions

The following conclusions have been drawn as a result of the tests described herein:

1. In damp atmospheres containing hydrogen sulfide, or in enclosures above septic sewage, raw sludge, or digested sludge, the following metals showed little or no attack at the end of 18 months: stainless steel, types 410, 430, 304, and 316; aluminum 17 ST; and nickel alloys, Monel metal, and Inconel metal.

2. In damp atmospheres containing free chlorine none of the metals tested proved satisfactory.

3. Stainless steels that proved satisfactory after 31 months of exposure in direct contact with digested sewage sludge coagulated with chlorinated copperas included Types 317 and 316, and Armco 17–14 Cu-Mo.

4. Stainless steels that proved satisfactory after 31 months of frequent exposure to the spillage of freshly dewatered vacuum filtered sludge cake included Armco 17–7 PH and Type 304. Results almost as satisfactory

were obtained with Type 431 and Armco 17–4 PH.

Acknowledgments

The Back River sewage treatment works, where the foregoing experiments were conducted, is under the general direction of P. L. Holland, director, Department of Public Works, and John J. Hunt, sewerage engineer. Dr. Abel Wolman is consultant to the Department of Public Works. R. J. Trautman, principal associate engineer, has direct supervision of the sewage works, and Paul L. Smith is plant superintendent.

Acknowledgments are due A. C. Burton and G. C. Pierpont of the research laboratories of the Armco Steel Corporation, who prepared the samples and calculated the corrosion rates; F. L. LaQue of the International Nickel Company, who furnished test samples for the first group of tests; and the management of the Armco Steel Corporation for permission to publish this paper.

SECOND QUARTER CONTRACTS TOTALLED $41,800,000

During the second quarter of 1952, an investment of $41,842,500 was made by 144 cities as their share of the job of keeping the nation's water resources free of sewage and other wastes, according to a recent report by the U. S. Public Health Service.

The report indicates a 30 per cent increase in the number of contracts awarded for sewage treatment plant projects over the first quarter of 1952. The dollar value of the contracts increased by 50 per cent. However, the total dollar value for the first half of 1952 is about the same as for the comparable period of 1951.

In releasing the quarterly report, Dr. Leonard A. Scheele, Surgeon General of the Public Health Service, said that the work of state and interstate water pollution control agencies is largely responsible for the accomplishments to date.

Thirty-six states and the District of Columbia are represented on the list of projects reported for the second quarter. Of the 144 projects, 75 are for new plants and 69 are for replacements, additions, or enlargements. Of the 75 new plants, 7 are in Wisconsin, 6 each in Texas and Oregon, 5 in Pennsylvania, 4 each in Colorado and New Jersey, and 3 each in Nebraska, Minnesota, and Maryland. The remaining 34 plants are scattered in 22 states.

The report is based on data obtained from state water pollution control agencies, the F. W. Dodge Corporation, and other construction news sources.

AERATION EFFICIENCY AND DESIGN

I. Measurement of Oxygen Transfer Efficiency

By W. Wesley Eckenfelder, Jr.

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The aeration efficiency of any unit is a function of the physical characteristics (depth, diameter, etc.) of that unit, the characteristics of the system's ability to break up and disperse the applied air, and physical and chemical variables of the substrate being aerated.

Aeration is employed in sewage and waste treatment practice in two basic ways; namely, in those systems which involve substantial oxygen demand requirements, such as activated sludge aeration tanks, and those systems which do not involve substantial oxygen uptake rates, as in pre-aeration of sewage or waste.

Oxygen is supplied to the system by diffusion from air bubbles as they rise through the liquid. The air may be introduced through porous media, whereby the mixing, agitation, intensity, etc., are all provided by the energy of the air. Air may also be supplied to the system using an open air discharge or diffuser and an agitator (rotor). In this case the agitation is produced by both the rotor and the air.

Notation

The following letter symbols have been adopted for this paper:

A = aeration area per unit volume of liquid, sq. ft. per cu. ft.;

C = oxygen concentration, p.p.m.:
- C_L = oxygen concentration in liquid phase at time t, p.p.m.;
- C_1 = initial oxygen concentration, p.p.m.;
- C_2 = final oxygen concentration, p.p.m.;
- C^* = oxygen concentration at saturation, p.p.m.;

E = efficiency of oxygen transfer, per cent;

G_s = oxygen supplied, lb. per hr. per gal.;

K, or k = a rate coefficient:
- K_d = oxygen transfer rate coefficient, lb. per hr. per gal.;
- k_d = oxygen transfer rate coefficient, p.p.m. per hr. per unit (p.p.m.) concentration gradient;
- k_r = oxygen uptake rate coefficient, p.p.m. per hr. per unit of activated sludge;

P = air pressure, lb. per sq. in.:
- P_{760} = air pressure corrected for barometric pressure, lb. per sq. in.;

R, or r = a rate:
- R_d = rate of oxygen transfer from the gas to the liquid, lb. per hr. per gal.;
- R_r = rate of oxygen uptake, lb. per hr. per gal.;
- r_d = rate of oxygen transfer from the gas to the liquid, p.p.m. per hr.;
- r_r = rate of oxygen uptake, p.p.m. per hr.;

T = absolute temperature;

t = time, hr.;

V_s = superficial air velocity, ft. per sec.; and

W = solids concentration, g. per l.

Theory

The rate of absorption of oxygen in water is directly proportional to the oxygen deficiency of the water, directly proportional to the aeration area (total area of contact between the air bubbles and the water surface), and the temperature. Kessener *et al.* (4) expressed this as

$$\frac{dC}{dt} = 0.00594\,A\,(T-239)(C^* - C_L) \quad (1a)$$

The term $0.00594\ A\ (T-239)$ has been defined as k_d, the oxygen transfer rate coefficient in this study. Gaden (3) has defined k_d as the product of the liquid film coefficient and the area of transfer, in which the liquid film coefficient is a function of the agitation intensity and the contact time. When oxygen is being removed from the system, a term $k_r\ W$ must be added. Thus, the general equation for oxygen transfer in biological processing units is (3)

$$k_d\,(C^* - C_L) = K_r\,W + \frac{dc}{dt} \quad (1b)$$

or,

$$\frac{dc}{dt} = k_d\,(C^* - C_L) - k_r\,W \quad (1c)$$

In the case of aeration when there is no appreciable oxygen uptake rate in the system, $k_r\ W$ approaches zero and the resulting equation will be

$$\frac{dc}{dt} = k_d\,(C^* - C_L) \quad (2a)$$

which integrates to

$$2.303 \log \frac{(C^* - C_1)}{(C^* - C_2)} = k_d\,t \quad (2b)$$

From Eq. 2*b* the time required to raise the dissolved oxygen from C_1 to C_2 at any given air flow may be determined. In the pre-aeration of most sewages and wastes $k_r\ W$ is not zero, but has been found to be of the order of 2 to 5 p.p.m. per hour depending on the waste strength and characteristics. Some industrial wastes may exert an appreciably higher demand rate. In these cases Eq. 1*b* must be employed.

In the activated sludge process, in the aerators, there is a substantial oxygen uptake rate, r_r, which is a function of the B.O.D. removed by the organisms, the detention time, the solids concentration, and the quality and character of the sludge. As a function of the solids concentration

$$r_r = k_r\,W \quad (3)$$

in which k_r is the oxygen uptake rate per unit of solids concentration.

In aeration tanks it may usually be assumed that steady state conditions exist at any one point in the aerator at any time. This means that there is no substantial change in dissolved oxygen concentration of the liquor with respect to time. Under these conditions it may be assumed that the quantity of oxygen transferred from the gas to the liquid state will be equal to the quantity of oxygen taken from the liquid state by the organisms, hence

$$r_r = r_d \quad (4)$$

in which r_d is the rate of oxygen transfer from the gas to the liquid state and is a function of submergence depth, rotor speed (when an agitator is employed), air flow, tank diameter, bubble size, surface tension, etc. At the interface between the air bubbles and the liquid mass, the oxygen must pass through a gas film followed by a liquid film resistance at the surface. Upon reaching the body of the liquid, the oxygen must pass through a liquid phase resistance to the sludge (cells). A resistance is also encountered (liquid film) at the sludge interface. All these resistances are assumed to be in series (1). It is generally assumed that the liquid film resistance controls the rate with a sparingly soluble gas such as oxygen (3). No effort is made in this paper to discuss the detailed diffusion mechanisms and their significances. Hence, under steady state

conditions

$$r_d = k_d (C^* - C_L) = r_r \ldots . (5)$$

In a sludge aeration system, r_r, C^*, and C_L may be measured, and k_d may be calculated for any air flow.

The rate at which oxygen will be absorbed is a function of the area of contact, the agitation intensity (time of contact), and the concentration gradient (oxygen deficiency). The absorption rate coefficient, k_d, will be affected by only the first two of these and will change as the applied air rate changes, with the dispersing mechanism, and with physical properties of the system, such as surface tension, viscosity, density, etc. The value of k_d will be proportional to the total interfacial area per unit of tank volume and will depend on the size and number of bubbles per unit of tank volume. This coefficient has been found to be a convenient measure of a system's capacity to absorb oxygen under specified conditions (1). The size of the air bubbles will vary with the rate of air application and will be affected by the mode of air entry and the degree of agitation. The introduction of detergents and other surface active agents will reduce the value of k_d and the oxygen transfer efficiency, as the high diffusion resistance encountered will be more important than the relative increase in total surface area (1).

The efficiency of oxygen transfer will determine the total volume of air which must be supplied to a system and is a linear function of the concentration gradient, $(C^* - C_L)$ (3). Thus,

$$E = \frac{K_d}{G_s} (C^* - C_L) \ldots . (6)$$

Depending upon such variables as the B.O.D., the solids concentration, and the detention time in the aerator, r_r has been found to be 15 to 55 p.p.m. per hour for normal domestic sewage employing conventional detention periods and mixed liquor solids. Practically speaking, the value of r_r will vary with the detention time through the aerator, being a maximum at the beginning and tapering to a relatively constant value toward the end.

The value of k_d may be determined by Eq. 5 when steady state conditions exist. This would be true when there is no sudden change in applied loading or applied air with respect to time.

Experimental

To obtain the value of k_d, a sample is drawn from the aeration tanks at a point slightly below the surface and the dissolved oxygen is measured. Due to the oxygen uptake rate of the organisms, it is desirable to record the time of sample collection and determination of dissolved oxygen and make a correction to compensate for the oxygen removed by the organisms. The oxygen uptake rate is also measured at this point, as well as the saturation value. The saturation of oxygen in sewage was found by Moore (2) to be approximately 95 per cent of that in distilled water. Industrial wastes will vary in their saturation characteristics.

It was found that the amperometric technic similar to that employed by Gaden (3) and Barthelemew and his co-workers (1) would be applicable to these studies. A Sargent manual polarograph, standardized according to the method of Seaman and Allen (5), was used.

To determine the oxygen uptake rate, a sample was drawn from the unit by means of a 50-ml. clinical syringe to avoid agitation and aeration. The sample was then placed in the polarographic cell, where the galvanometer deflection was read at 1-min. intervals until the dissolved oxygen was sufficiently exhausted from the sample and the galvanometer deflection approached zero (the galvanometer deflection at zero dissolved oxygen will depend upon the adjustment of the instrument, and the current level established by other substances that are reducible at the

dropping mercury electrode and which may be contained in the sample). From these data a straight line is obtained, as the relation between dissolved oxygen utilization and time is a linear one down to the critical oxygen concentration. The slope of this line is denoted as r_r, or the oxygen uptake rate. In those cases where the dissolved oxygen in the sample at the time of collection is too low to obtain a curve, the sample is aerated to obtain a build-up of dissolved oxygen and then the depletion measured with respect to time as above.

The measured dissolved oxygen in the tank at any time may be obtained either by extrapolation of the oxygen utilization curve to zero time, or by obtaining the time difference between sampling and measurement and adjusting the dissolved oxygen concentration by adding that amount removed from the sample by the organisms in the measured time interval. This time interval between sampling and measurement should not exceed 1 to 2 min. The oxygen transfer rate coefficient is then calculated from Eq. 5.

The value of k_d may also be measured employing a non-steady state method in which the oxygen concentration is changing with respect to time. The basic relationship (Eq. 1) may be transposed to

$$(C^* - C_L) - \frac{k_r W}{k_d} = \frac{1}{k_d}\frac{dc}{dt} \quad \ldots (7)$$

and by integrating between the limits of $t = 0$ to $t = t$,

$$(C^* - C_L) = \left(C^* - \frac{k_r W}{k_d}\right) e^{-k_d t} + \frac{k_r W}{k_d} \quad (8)$$

The term $\left(C^* - \frac{k_r W}{k_d}\right)$ is the apparent saturation value for any given system, since $\frac{k_r W}{k_d}$ is the deviation

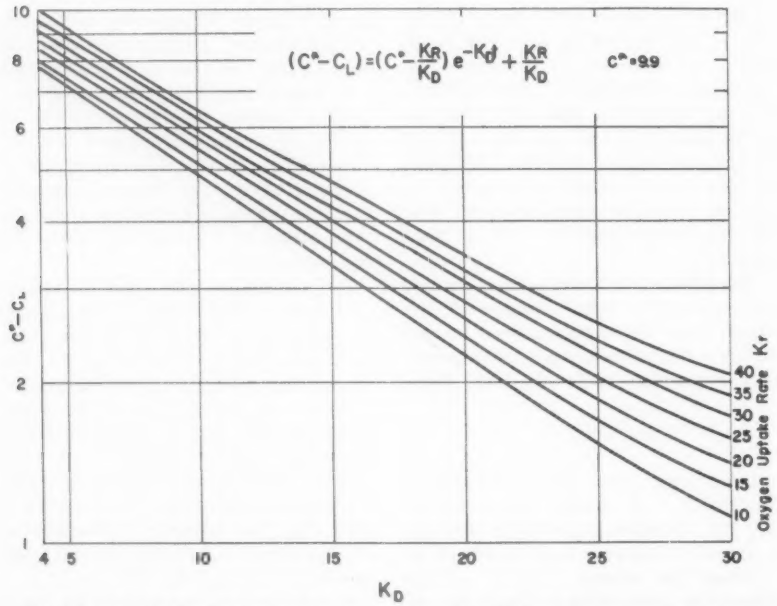

FIGURE 1.—Calibration curve for oxygen transfer efficiency measurement; 5-min. time interval.

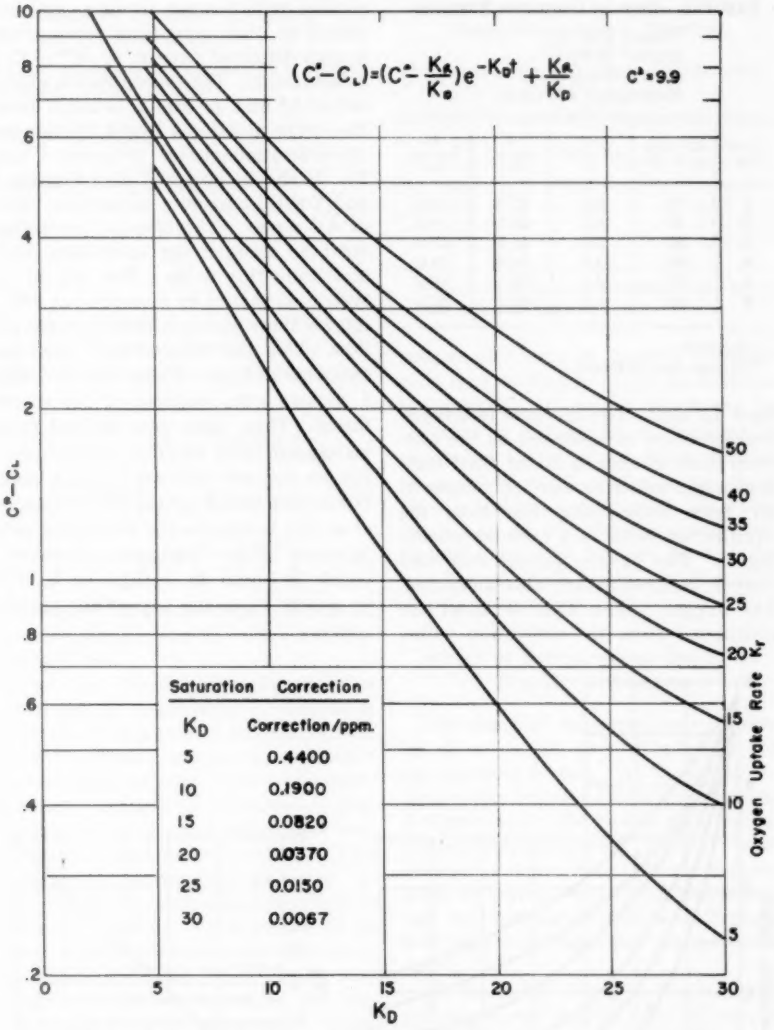

FIGURE 2.—Calibration curve for oxygen transfer efficiency measurement; 10-min. time interval.

from saturation which will exist as a result of the continuous oxygen uptake rate $k_r W$ and the rate of oxygen addition. Hence, in steady state operation t approaches infinity and Eq. 8 becomes Eq. 5.

To measure the value of k_d employing the non-steady state method, the air to the unit is turned off and the dissolved oxygen is allowed to approach zero. The air is then applied at the desired rate and samples are taken at 1-min. intervals for dissolved oxygen measurement for a period of at

TABLE I.—Data for Illustrative Example [1]

Temp.: 13.5° C.
Depth: 33 in.
Sat.: 9.90 p.p.m.
Rotorspeed: 600 r.p.m.

Curve No.	Air Flow (cu. ft./hr.)	(C^*-C_L) [2]	r_r (p.p.m./hr.)	k_d (p.p.m./hr.)
1	33	5.1	27.5	8.2
2	39	4.3	30.5	9.8
3	52	3.5	31.5	12.0
4	64	2.8	34.4	15.0
5	77	2.2	33.4	18.2
6	92	1.5	32.2	23.5

[1] See text.
[2] 10-min. time interval.

least 10 min. The increase in oxygen concentration is measured as the concentration of oxygen in the fluid mass is changed under an applied volume of air from some value less than the equilibrium value to a value approaching it. The oxygen uptake rate and oxygen saturation are also measured. The oxygen values thus obtained are subtracted from the saturation value, plotted with respect to time, and adjusted so that zero time corresponds to zero dissolved oxygen, or $(C^* - C_L)$ = saturation. The concentration gradient at 10 min. or 5 min. is taken from the curve and k_d is found by the use of calibration curves (Figures 1 and 2). It should be noted that Figures 1 and 2 are based on a saturation value of 9.9 p.p.m. Therefore, a correction must be made if the saturation deviates from this value. For any given system k_d should be measured at varying air flows and k_d plotted against air flow. This plot will generally be of the exponential type. Figure 3 and Table I illustrate an example of the calculation. These data were derived from an experimental aeration tank employing an agitator and air sparger ring. It has been found convenient by Cooper *et al.* (6) to express the absorption rate in terms of an "absorption number" which is equal to $k_d/G_s n$ or $k_d/V_s n$ in which V_s is the superficial air velocity.

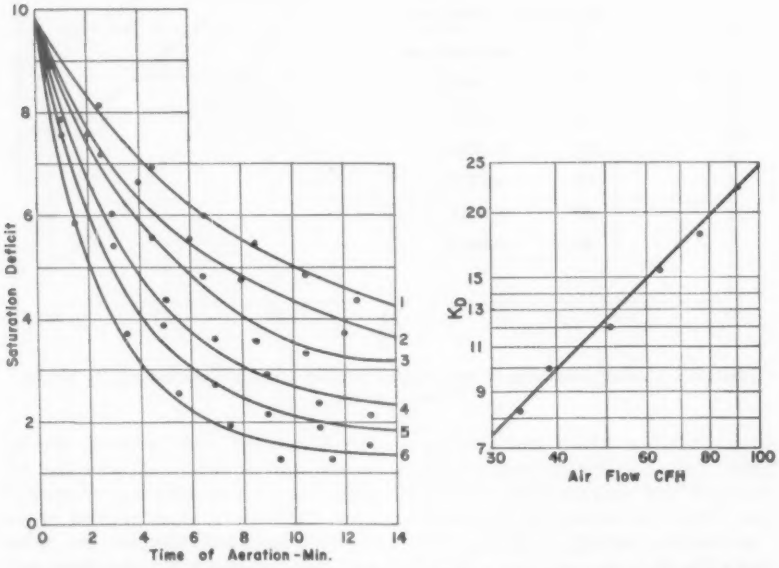

FIGURE 3.—Illustrative problem in oxygen transfer measurement and calculation.

Oxygen Transfer Efficiency Measurement

The efficiency of an aeration system may be defined as the

$$\frac{\text{weight of oxygen absorbed per unit of time}}{\text{weight of oxygen supplied per unit of time}},$$

or

$$E = \frac{R_d}{G_s} = \frac{R_r}{G_s} \quad \ldots\ldots\ldots (9)$$

But G_s is dependent on the air density, p, which in turn is related to the temperature and pressure of the air; that is,

$$G_s = \text{air flow (c.f.h.)} \times \text{density} \left(\frac{\text{lb.air}}{\text{cu.ft.}}\right) \times 0.232 \left(\frac{\text{lb.O}_2}{\text{lb.air}}\right) \times 1/\text{gal.} \ldots (10a)$$

$$P = 0.0808 \frac{P_a}{14.7} \left(\frac{492}{T_f}\right) \ldots (10b)$$

in which P_a is the average pressure of the applied air and T_f is the average temperature.

For any aerating system under a given set of conditions, k_d will be a constant (a function of the bubble size, time of contact, tank depth, and other factors characteristic of the equipment, aeration device, and substrate). The transfer efficiency will vary as the concentration gradient maintained. This variation is linear, the efficiency increasing as the concentration gradient increases. Hence, it is desirable at all times to maintain the maximum concentration gradient which can be sustained without detriment to the biological life active in the process. Table II gives the absorption efficiencies obtained from the example shown in Figure 3 by employing Eq. 9.

Effect of Agitation Intensity and Turbulence

The intensity of agitation and the turbulence produced has a profound effect on the aeration efficiency and the process efficiency in general. Sludge cells tend to clump, hence, to decrease the quantity of oxygen which can be transferred to them by an increase in resistance to transfer. High degrees of agitation tend to break up these clumps and hence to increase the transfer rate to the cells for the metabolism. Direct contact is favored by a large number of small bubbles and a high degree of agitation (1).

TABLE II.—Oxygen Absorption Efficiency (Measured at 2.0 p.p.m. Dissolved Oxygen)[1, 2]

k_d (p.p.m./hr.)	Air Flow (cu. ft./hr.)	Eff. (%)
8.2	33	15.4
9.8	39	15.5
12.0	52	14.6
15.0	64	14.5
18.2	77	14.7
23.5	92	15.7

[1] Based on air density of 0.0892 lb. per cu. ft.
[2] See text and Figure 3.

Effect of Submergence Depth on Transfer Efficiency

The depth of submergence will have an effect on the over-all efficiency of the aerating system. As the depth increases the transfer efficiency increases. Unfortunately, the power required increases approximately linearly with increasing depth also, so that a balance must be arrived at between power saving by increased transfer efficiency and power increase due to increased depth.

As the liquid depth in the tanks increases, the saturation value of oxygen in the liquid also increases, due to the increased pressure of the entering gas. To compensate for this, the saturation value of oxygen must be corrected by the factor $P_{14.7}/14.7$. Kessener *et al.* (4) found that in a deep tank the pressure correction exceeds the barometric pressure by something less than one-half the head of water above the aerating unit.

The total quantity of oxygen transferred will vary directly as the retention period of the air bubbles in the liquid, since the small quantities of oxygen normally absorbed will not seriously affect the depletion of oxygen within the bubbles. The velocity of the bubbles will be influenced by their size and by the density and viscosity of the fluid mass. It has been found that in most sewage application the upward velocity of the bubbles is essentially the same for all bubbles down to ⅛-in. diameter and is equal to 0.75 ft. per sec. in still water. The oxygen transfer efficiency will vary as the time of contact of the gas bubbles with respect to depth.

Effect of Temperature

Changes in temperature affect the value of k_d, since the rate of oxygen diffusion through a liquid is affected, rising temperatures increasing the value of k_d. Rising temperatures also result in a decrease in the saturation value of oxygen, so that these two factors tend to cancel each other in the normal working range.

Summary and Conclusions

The quantity of oxygen which may be transferred in an aerating system may be expressed in terms of an oxygen absorption rate coefficient, k_d, which is a function of the bubble size, the number of bubbles, and their time of contact in the liquid medium, in addition to physical and chemical variables of the substrate being aerated. The oxygen transfer efficiency is a function of k_d and the concentration gradient maintained in the system.

Two methods are evaluated for the measurement of the oxygen transfer rate coefficient, k_d, and the oxygen transfer efficiency of a system. Curves are presented to permit an operator to rapidly ascertain the oxygen transfer characteristics of a system from a series of dissolved oxygen measurements.

In this investigation the polarographic method of measuring dissolved oxygen was employed. The polarograph was standardized using 1 per cent KCl. The oxygen uptake rate was measured by saturating a sludge sample with oxygen and noting the decrease in oxygen concentration with respect to time.

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A STUDY OF BIOLOGICAL SEWAGE OXIDATION USING RADIOPHOSPHORUS AS A TRACER

By Richard Rorschach and George W. Reid

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To date, most biological treatment research has been accomplished by studying plant operation and stream performance on large pilot plants. In conducting research under these conditions, many difficulties have been encountered (1)(2)(3)(4) which basically were a result of size and consequent inflexibility.

In developing a small, flexible pilot plant for biological treatment, provision must be made for the following elements:

1. Attached or suspended culture of the microorganisms responsible for the bio-oxidation of the waste (food).
2. Maintenance of the necessary air and food supply for the culture.
3. Incorporation of some device for the quantitative determination of the rate of utilization of the waste by the microorganisms.

Complete flexibility as to quantities and concentration of these elements should be structurally provided for and a criterion for pilot-prototype similitude must be selected which delineates the relationship of the reaction rates of the pilot unit and the prototype.

Basic Considerations

A study of bacterial growth rates—such as that of *Zooglea ramigera*, which according to Butterfield and Wattie (5), Grune and Eliassen (6), Phelps (4), and the authors, is the one responsible for bio-oxidation of sewage—had indicated two characteristic growth curves. When Butterfield (7) grew bacteria in a series of flasks in which the food concentrations were varied, he found that the numbers of bacteria always rose rapidly to a fixed ceiling and remained there or slowly declined. This ceiling value was definitely related to the food concentration and had an almost linear relationship to it.

In another series of experiments from the same laboratory (8) it was found that during the early stages of growth, when the growth is approximately geometrical, oxidation proceeded, but at a decreased rate as the growth approached a ceiling. When the growth became static at high numbers, the oxidation rate became zero or nearly so. It appears to be the rate of growth rather than mere numbers which determines the oxidizing power of the bacteria.

The resulting S-shaped curve is illustrated in Figure 1. Curves of this general type are frequently found to express the course of a chemical reaction the velocity of which is accelerated by the presence of a catalytic agent, the latter being a by-product of the reaction. Such reactions are called autocatalytic. Such a reaction approaches an upper limit asymptotically.

In Butterfield's work (7)(8) the exact nature of the limiting factor is not clear. It does appear, however, to be associated with some effect of crowding; greater individual numbers of a smaller species of organism appear at the ceiling value. There appears to be an equilibrium between the concentration of bacterial substance and the concentration of food substance.

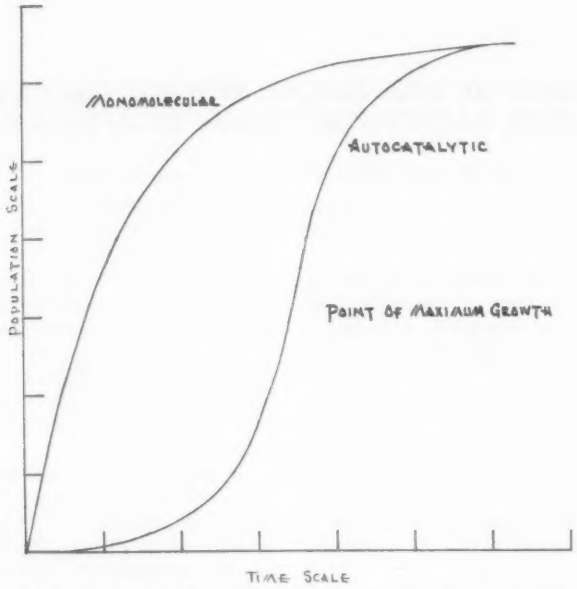

FIGURE 1.—Comparison of monomolecular and autocatalytic growth curves.

In any mixed population of bacteria and predators, an equilibrium condition may be visualized in which the predator population will be supported, without increase or decrease, by the new bacterial cells as they are developed. This level of population will be very near the point of maximum bacterial growth.

If the food supply is maintained at its existing level, this equilibrium condition will continue indefinitely. This may be the case in a trickling filter where there is a continuous flow of settled sewage, and the predator might be thought of as the bacterial sloughing action common to such filters. However, in a polluted stream undergoing self-purification the food concentration is continuously being lowered. This brings about a continuous reduction in the ceiling limit of the bacterial population, of the maximum rate of increase of new bacteria, and of the predator population being supported by the bacteria. Thus, there is a continual readjustment of the balance to the steadily decreasing food supply whereby the rate of bacterial increase is automatically maintained at a maximum level and almost in proportion to the concentration of available food.

Something similar to the monomolecular law, which is indicated graphically in Figure 1 with the autocatalytic curve, might be arrived at from this reasoning. The monomolecular relation is a relation of a bacterial population which has already been established, while the autocatalytic relation is one of a system in which the growth started from a low level and is in the process of being established. These growth curves can be formulated as follows (3):

Monomolecular

$$\frac{dy}{dt} = k\,L_t \quad \ldots\ldots\ldots (1)$$

Autocatalytic

$$\frac{dy}{dt} = k_1 L_t + k_2 L_t y \quad \ldots\ldots (2)$$

in which y = growth at time t, and L_t = the growth still to be accomplished, or $L_t = (L\text{-}y)$, where L is the upper limit asymptotically. The values of k, k_1 and k_2 are known as the reaction or velocity coefficients, or just k-factors.

The authors have selected the k-factor to delineate pilot-prototype similitude. The way in which the k-value varies will be noted with much interest. For, according to Phelps (4) and others, this is primarily the distinguishing factor between trickling filter operation, activated sludge operation, and stream purification. In trickling filter operation, the k-value remains rather constant throughout the operation. Under ordinary conditions of operation, the actual time of passage of the liquid through the filter is a matter of perhaps 15 or 20 min. Yet within this brief period removal of B.O.D. to the extent of 75 or 80 per cent may be accomplished. Phelps indicates that this removal is due to a "holding action" accomplished by the slime on the filter rocks. In other words, sewage is put onto a filter and the oxidizable material is taken up by the jelly-like slime and held for a matter of about 4⅓ days. During this time it will be oxidized by the organisms contained in this slime, designated *Zooglea ramigera*. This will correspond to a normal oxidation rate of 23 per cent per day. The system will then be just in equilibrium and oxidation is "normal."

However, in channel experimentation and activated sludge experimentation (9) it appears that there are different rates of oxidation corresponding to different times in the oxidation cycle. Phelps (4) explains it in this manner:

> Consider that B.O.D. of whatever sort or from whatever source, represents oxidizable organic matter, and the rate at which it is oxidized is determined wholly by the circumstances. Any accumulation or storage of this matter, whether it be in the activated sludge mass, in a trickling filter slime, or in the active material which accumulates on the bed of a polluted stream, has built up a biological population in equilibrium with its food supply, which is a necessary condition for the normal B.O.D. rate. A fresh feeding, concentrated within this mass by absorption, immediately stimulates this population to rise to new heights or a new ceiling of growth and a new equilibrium. Pending the establishment of this new condition, the rate of oxidation of all the oxidizable material present is accelerated.

Streeter and Phelps (3) showed that the reaction coefficient, or k-value, is also the distinguishing factor for stream flow. In their study of the Ohio River below Cincinnati, from May, 1914, to June, 1915, they determined that the k-factor was 0.12, as compared to the B.O.D. value of 0.1.

The following values of k have been determined from prototypes (4):

B.O.D. reaction	0.1
Streams	0.12
Activated sludge	0.13
High-rate trickling filters	0.1505
Slow-rate trickling filters	0.175

Bacterial numbers and oxygen utilization have been used to determine k. Reid (11), using radioactive phosphorus as a tracer in studying the slimes found in sinks and traps, showed that P^{32} is metabolized by slime and that a plot of the uptake of P^{32} *vs.* t for slimes is similar to the curves encountered in B.O.D. and bacterial studies. Grune and Eliassen (6) found that P^{32} when present in concentrations at or below 10 mc. per l. exerts no significant effect on the following parameters in the first stage of the biochemical oxidation of sewage:

1. The reaction velocity constant of biochemical oxidation, k.
2. The ultimate first-stage B.O.D. value, L.
3. The 5-day B.O.D., $y_t - 5$.

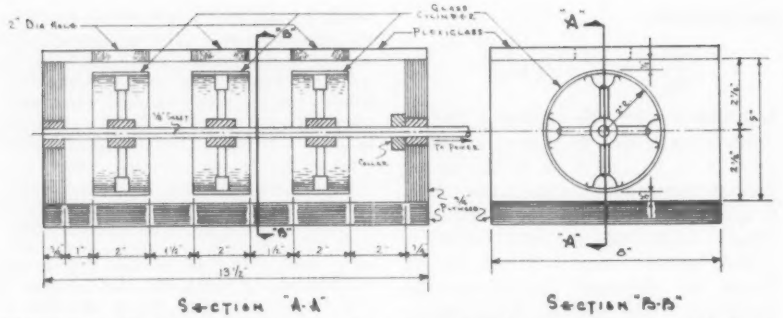

FIGURE 2.—Details of apparatus for detecting radioactive uptake by bacterial slimes, molds, etc.

Experimental Procedure and Apparatus

The authors have devised an apparatus whereby:

1. The sewage slime is grown on a glass cylinder.

2. The cylinder is rotated through a bath of 250 ml. of sewage or waste, thus producing water-air-slime interfaces at will.

3. The bio-oxidation rate of the sewage by the slime is determined by detecting quantitatively the uptake rate of P^{32} from the sewage by a G–M tube located above the rotating cylinder and screened from the sewage. An elevation and a section of the apparatus are shown in Figure 2, and a photograph including the counter and recording apparatus in Figure 3. The 3/8-in. shaft and the arms holding the glass

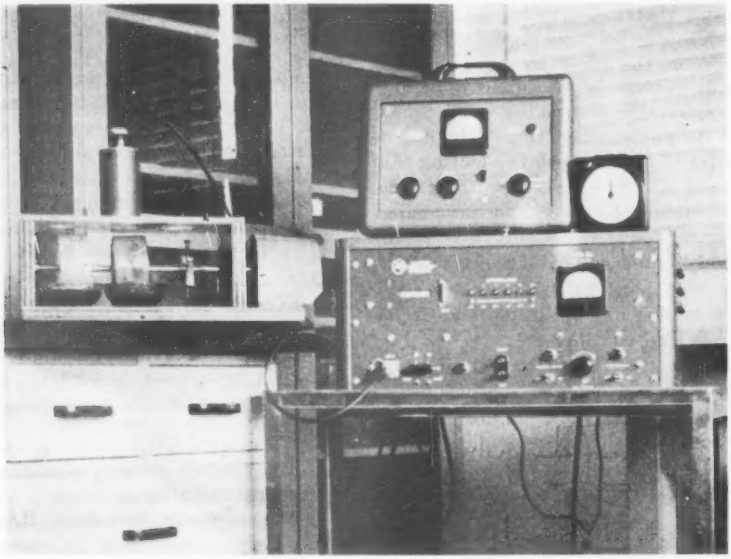

FIGURE 3.—Laboratory sewage oxidation plant and radioactive counting apparatus.

cylinders are made of brass. The friction springs on the brass arms are of copper. There is a break in the shaft at the collar to allow the complete shaft assembly to be removed from the framework. The dishes containing the synthetic sewage tagged with the radioactive phosphorus are put into place under the cylinders when the shaft assembly is removed. The shaft assembly revolves at 2 r.p.m., which is approximately the rate of wetting of the filter rocks in a trickling filter operation.

The Geiger-Mueller tube in a shielded probe is placed over the 2-in. diameter hole in the Plexiglass top. The tube and the Plexiglass top are marked so that the tube will be set in the same position each time a count is taken.

The dishes are any which will fit into the apparatus and allow satisfactory operation of it. These dishes hold 250 ml. of synthetic sewage.

The medium (synthetic sewage) used to establish initial growth was 1.5 g. peptone and 2.5 g. beef extract per 1,000 ml. of Norman, Okla., tap water. This is half strength of the nutrient broth recommended in "Bergey's Manual" (10) for maximum growth of *Zooglea ramigera*. This gives a very satisfactory medium for the growth of the slime with no appreciable odor. B.O.D. of this medium is about 500 p.p.m.

Growth was initiated on the glass cylinder by suspending it in the effluent at the Norman sewage treatment plant, and at the South Side treatment plant in Oklahoma City. After one week, the cylinder was inspected and found to have a golden-brown growth fairly well established.

Microscopic examination of the slime, together with the environment in which it was obtained, indicated that a typical sewage slime was obtained. The cylinder was placed in the apparatus and the slime was fed with synthetic sewage.

At first there appeared to be no increase in the growth on the cylinder. This was thought to be a result of the toxic effect which the copper, used as springs to keep the cylinders on the axle, might have on the slime. To correct this possible condition, the springs and the brass arms were coated with clear lacquer. Good growth resulted immediately. This growth had resulted from adding medium whenever the supply in the dish became low, principally through evaporation. Upon a complete change of the medium, however, there was a sloughing of the slime from the cylinder. Sloughing might have been due to dismounting the cylinder when the medium was changed; a change in osmotic pressure might have caused the sloughing.

To correct the sloughing, which might have been due to the smoothness of the glass cylinder, or the change in osmotic pressure, or both, the medium was changed with a pipette, thereby eliminating dismounting of the cylinder; calcium chips were added to the medium; and the cylinders were coated with lacquer.

When a good growth was established, the B.O.D. of the medium was reduced to 250 p.p.m., while retaining the pH at 7.2, and holding the temperature at 20° C. P^{32} was injected into the sewage.

The number of injections was varied so that a range of solutions from approximately 0.1 to 1.0 microcurie per liter was obtained. The procedure was to begin with low-level activity and proceed to higher levels as the experiment progressed. This was done in order that the same slime could be used. Counting was begun in the morning and continued for 12 to 13 hr., depending on when the uptake ceased $\left(\frac{dP^{32}}{dt} = 0\right)$. Readings were taken every hour.

After the counting was finished, the medium used in that run was removed and replaced by fresh medium with no P^{32} added. At the beginning of the

next run the medium was again changed and injected with P^{32}. This was done in an attempt to leach out some of the P^{32} from the slime as indicated by Reid (11)(12).

It was desirable to be certain that only the radiation attributable to that absorbed and assimilated by the slimed surface be recorded.

Reid *et al.* (11) have shown that the tracer will not penetrate the slime layer, regardless of its thickness, and adhere to the surface of the glass cylinder. In other words, the slime layer will absorb the tracer before it can get through to the cylinder and will not influence the count by absorption on the cylinder surface.

There appear to be two other factors which might affect the count. First, due to a coating of slime inside the cylinder and a resulting absorption of the tracer by this coating, there may be radiation from the inside of the cylinder that will influence the count. This radiation was determined in the following manner. A small area of the inside of a clean cylinder was coated with a known quantity of tracer with a certain level of activity. This was allowed to dry and a count was taken with the cylinder at rest. The same procedure was repeated except that the tracer was placed on the outside of the cylinder. Then the radiation from the inside was compared to that from the

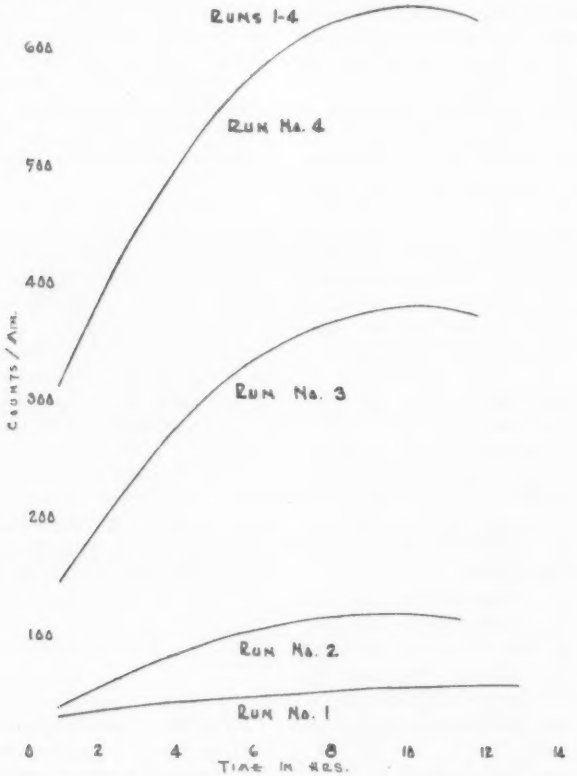

FIGURE 4.—P^{32} uptake curves for synthetic sewage.

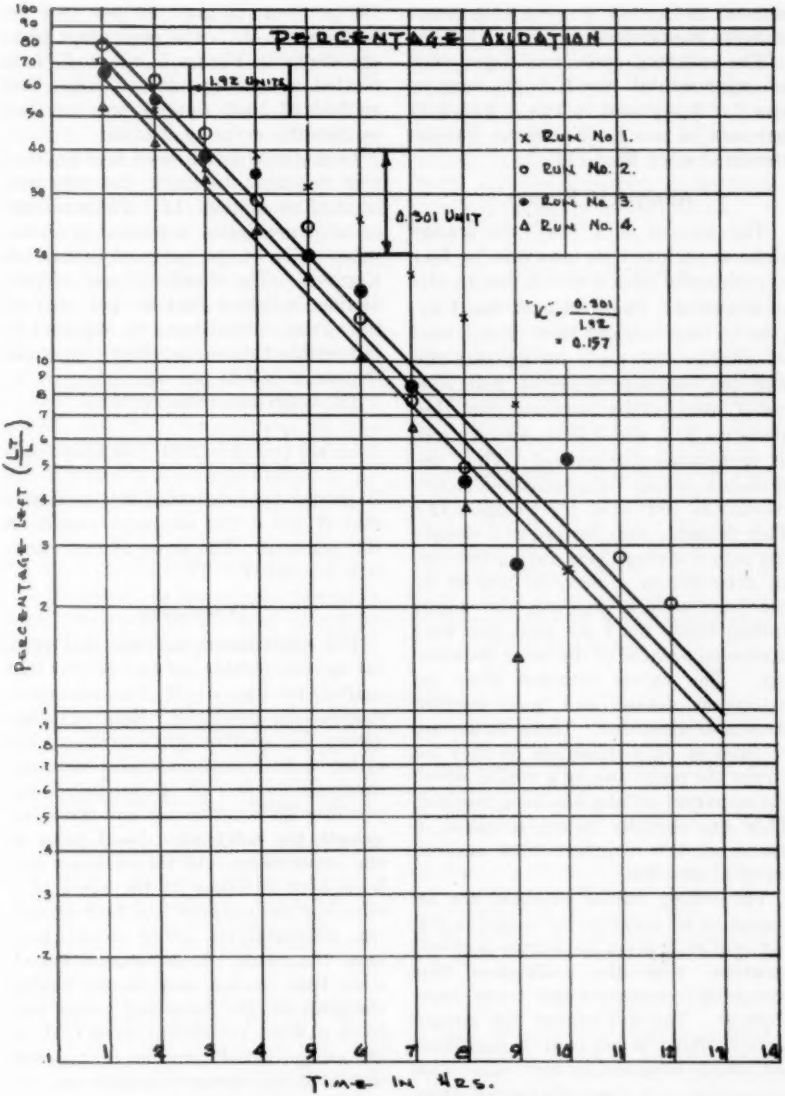

FIGURE 5.—Percentage of oxidation at various times.

outside and a percentage of one to the other was found. Of the gross count, 2.5 per cent was caused by radiation from the tracer taken up by the slime inside the cylinder.

The other factor, direct radiation from the medium around the cylinder, might have influenced the count. Therefore, a count was taken with the cylinder at rest. There was no sig-

nificant difference between this count and the background.

The counting error was 2 per cent in experimental run 1, 1 per cent in run 2, 0.5 per cent in run 3, and 0.35 per cent in run 4. This error was determined after Reid (12).*

Analytical Results

The uptake of P^{32} by the sewage slime at various time intervals for four experimental runs is shown graphically in Figure 4. The results of run 1 appear to be a straight line. A low level of activity was used during that run and the counting error at that level could very easily account for this. Runs no. 2, 3, and 4 show up very well as monomolecular curves. They approach a ceiling value and then slowly recede, as indicated by Phelps (12). This recession may be due to a sloughing action taking place during the run. In determining a curve of best fit by the least squares method, the points falling below the 1 per cent line were discarded because of the error in counting. The values obtained after the maximum uptake had been reached were also discarded. These values are of interest only inasmuch as they indicate the point during a run at which the apparent ceiling has been reached. They are actually values obtained in excess of the retention time encountered in practice.

The ceiling values obtained are assumed to be equal to the complete 100 per cent utilization for purposes of calculation, with the realization that sloughing certainly must lower these slightly. The net counts per minute were changed to per cent of maximum net counts obtained in each run. This percentage was then subtracted from 100 per cent to give the per cent remaining (L_t/L). The percentage plots are shown in Figure 5, where L_t/L is plotted on a sewage scale *vs.* time. The method of least squares was selected to give the curve of best fit.

In addition to curve of best fit, it is also desirable to know the standard error of prediction (13). The standard error of prediction is plotted as an envelop curve of the curve of best fit on Figure 5. The standard error of prediction indicates that 68 per cent of the values obtained can be expected to fall within this range. For these data the range is 9.85 per cent.

The equation of the curve is

$$\log\left(\frac{L_t}{L}\right) = 2.04 - 0.157\,t \ldots (3)$$

It should be noted that this indicates that if $t = 0$ the intercept would be 109 per cent. The slope of this curve is $k = -0.157$.

Discussion

The experiments indicate that typical monomolecular curves—or, for that matter, the upper half of autocatalytic curves—are produced. Reid (11) has shown on similar slime studies that either a full monomolecular or autocatalytic curve can be produced, depending on whether or not the slime growth has established itself prior to the experiment. If the cylinder had been free of slime at the start of a run, and the medium had been seeded, the autocatalytic curve would have been the result. It is common knowledge that sewage and wastes having the same oxygen consumed values may have a wide variability in B.O.D. in the early days, depending on the condition of the bacterial family and environment at onset.

The k-value obtained (-0.157) agrees with those found in other conditions of stream purification and sewage treatment. Other k-values range from -0.1 in the B.O.D. reaction to -0.175 in a slow-rate trickling filter.

* The counting geometry of the apparatus was determined by placing Ra D + E standard on the cylinder. The geometry was 18.3 per cent. The G–M tube was of the end-window type with a window thickness of 1.5 mg. per sq. cm. The disintegrations were recorded on an IDL 165 scaler.

Thus, once the k-value is in agreement with that found in streams, in trickling filters, or on activated sludge, the pilot plant can be studied with a tremendous degree of flexibility. For example, the effects of recirculation can be studied by adding fresh sewage at intervals. Changes in temperature can be effected by heating or cooling a mere 250 ml. of sewage; an alteration in the rotational speed will change the air supply. Such things as shock loading, toxic materials, etc., which are so common in sewage treatment, can be easily simulated and the limits of loading and rate of recovery noted.

The whole oxygen sag curve of a stream might be reproduced by the continuous adding of diluent, which in effect would be the equivalent of establishing a value of k_2, the reaeration constant.

Conclusions

A biological treatment pilot plant has been developed at the cost of $35.00 using inexpensive tracer levels of P^{32}, and requiring only 250 ml. of sewage or waste. The apparatus is correlated to the stream, sewage, and/or waste treatment prototype by the reaction coefficient k. The pilot plant is very flexible; almost any type of adjustment of time, food, flora and fauna, and air likely to be encountered in the prototype can be easily accomplished.

Acknowledgments

The authors wish to express their sincere appreciation to Woodrow H. Jones and Fred M. Buxton, graduate students at Oklahoma University; Marvin Buerklin, South Side sewage treatment plant, Oklahoma City; Floyd Larson and Joe Keeley, professors of civil engineering, University of Oklahoma; and Carl Doering, School of Public Health, for their advice and encouragement. The senior author presented this work in partial fulfillment of a requirement for the degree of Master of Civil Engineering at the University of Oklahoma.

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A STUDY OF SEWAGE CHLORINATION IN THE NEW YORK CITY METROPOLITAN AREA*

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In the New York City metropolitan area, the several regulatory agencies having jurisdiction and responsibility over the adjacent marine waters, in a conference on related problems, observed that there was considerable variation in practices and in results from the chlorination of sewage and sewage effluents. This led to a conference of representatives of all the official agencies having to do with the regulation and operation of sewage treatment in the metropolitan area, at which the problems and questions concerning the chlorination of sewage were reviewed.

A committee consisting of S. G. Hess, Interstate Sanitation Commission, Chairman; F. W. Gilcreas, Division of Laboratories and Research, New York State Dept. of Health; H. Udell, U. S. Public Health Service; M. H. Bidwell, New York State Conservation Dept.; W. Donaldson, New York City Dept. of Public Works; A. H. Herberger, Nassau County Health Dept.; R. M. McLaughlin, Westchester County Health Dept.; and W. H. Larkin, New York State Dept. of Health, was appointed to study the results of the conference and make recommendations for further consideration by the group. Other agencies represented in the conference group included New York City Dept. of Health, Westchester County Dept. of Public Works, Nassau County Dept. of Public Works, New Rochelle Dept. of Public Works, and New Rochelle Dept. of Health. No comparison of the data available among the different agencies could be made, owing to diverse methods of sample collection and laboratory examination. The committee, therefore, recommended to the parent body that a study of the bacteriological efficiency of chlorination of sewage plant effluents as indicated by uniform procedures be undertaken by five cooperating laboratories at ten different sewage treatment plants.

This recommendation was adopted by the conference and the same committee was instructed to carry out such a study. It was anticipated that the results would merely clarify the problem without providing final solutions of the numerous questions concerning the effectiveness of chlorination of sewage and sewage effluents.

The study was undertaken during June, July, August, and September, 1950, by four of the investigating agencies. The following table indicates the plants studied and the agency conducting the investigation.

* Presented at 1952 Annual Meeting, New York Sewage and Industrial Wastes Assn.; New York, N. Y.; January 17–18, 1952.

Plant	Agency
Jamaica	New York City Department of Public Works
Kings Park State Hospital	New York State Conservation Department
Oyster Bay Sewer District	New York State Conservation Department
Coney Island	Interstate Sanitation Commission
Great Neck Village	Nassau County Department of Health
Lawrence	Nassau County Department of Health

Plant Descriptions

A brief description of each plant follows:

Jamaica

The Jamaica plant is a modified aeration plant treating essentially domestic sewage from a combined system. Following racks, grit chambers, and fine screens, the sewage with return sludge is passed through aeration tanks and final sedimentation tanks with chlorination of the effluent during the summer months. Chlorine is added to the effluent line by solution feed chlorinators, and a tap located 480 ft. below the point of chlorine application continuously returns a small flow to the chlorine house from which samples were taken. The total flow time from the point of chlorine application to the tap in the chlorine house is 15 min. at average sewage flow and probably does not vary by more than ± 1 min.

Kings Park State Hospital

The Kings Park installation is an activated sludge plant with mechanical aeration. The sewage is from the institution only and passes through racks, primary settling tanks, aeration tanks, and final settling tanks. Chlorine is added by solution feed chlorinators to the settling tank effluent in a chlorine contact chamber with a detention period of about 20 min. The return activated sludge is chlorinated for control of bulking. Samples were collected at the outfall of the contact chamber.

Oyster Bay Sewer District

The sewage plant of the Oyster Bay Sewer District treats a dilute domestic sewage by sedimentation in an Imhoff tank. Chlorination of the settled effluent is practiced, using the outfall sewer as a contact chamber. Samples were collected at the point of chlorine application and held for 15 min. before the residual chlorine test was made and the sample dechlorinated for bacteriologic examination.

Coney Island

New York City's Coney Island plant is a chemical precipitation plant using copperas as coagulant. The total flow passes through grit chambers and is then divided, part flowing by separate line to circular sedimentation tanks and part to a flocculator and rectangular settling tanks. Chlorine and copperas are added to each line. Samples were collected at the entrance to the flocculator of the rectangular tanks, held for 15 min. before the residual chlorine test was made, and the sample dechlorinated for bacteriologic examination. The sample, therefore, contained copperas besides chlorine.

Great Neck Village

The Great Neck Village plant is a biofiltration plant. The raw sewage is collected in pump wells and partially chlorinated, but not sufficiently to produce residual chlorine. After primary sedimentation, the sewage is treated on a high-rate filter with a recirculation ratio of 3:1 and then settled in a secondary tank. Chlorine is added in a contact chamber where about 45-min. contact is provided at the present rate of flow. Samples were collected from the middle of the contact chamber because adequate mixing of chlorine and effluent could not be assured if samples were taken nearer the point of application.

Lawrence

Domestic sewage is treated in the Lawrence plant by primary sedimentation and separate sludge digestion. The primary effluent is chlorinated. Samples were collected at a manhole 25 ft. beyond the point of application and held for 15 min. before the residual chlorine test was made and the chlorine destroyed in the sample for bacteriologic examination.

Method of Testing

Uniform procedures for the collection of samples and laboratory exami-

nations were agreed upon before the study was started and the technical details were supervised by the Division of Laboratories and Research of the New York State Department of Health.

Samples were collected in sterile glass bottles and dechlorinated with sodium thiosulfate following 15 min. of contact between the chlorine and the sewage. Samples were collected hourly from 8:00 A.M. to 1:00 P.M., cooled immediately by immersion in cracked ice, and held at less than 5° C. until 3:00 P.M., when the laboratory tests were started. Thus, all samples were treated in a similar manner by

TABLE I.—Results of Bacteriologic Examinations under Various Ranges of Residual Chlorine Values

Plant	Residual Chlorine Range (p.p.m.)	No. of Samples	M.P.N. per 100 Ml.		
			Median	Maximum	Minimum
Jamaica	Unchlorinated	30	20,000,000	—	—
	0–0.19	17	4,300	46,000	9.1
	0.2–0.39	10	2,300	24,000	43
	0.4–0.59	15	430	4,300	3.6
	0.6–0.99	9	430	4,300	29
	1.0–1.3	9	43	230	3.6
Kings Park State Hosp.	Unchlorinated	30[1]	93,000	—	—
	Unchlorinated	3[2]	2,400,000	—	—
	0.5–0.99	19	9.1	240	<3.6
	1.0–1.49	28	9.1	2,400	<3.6
	1.5–4.0	10	9.1	240	<3.6
Oyster Bay Sewer Dist.	Unchlorinated	30	24,000,000	—	—
	0.5–0.99	11	430	240,000[3]	3.6
	1.0–1.49	20	335	9,300	7.3
	1.5–1.99	19	93	2,400	9.1
	2.0–3.0	7	43	430	9.1
Coney Island	Unchlorinated	30	46,000,000	—	—
	0	13	240,000[3]	240,000[3]	4,300
	0–0.49	6	78,000	240,000[3]	2,300
	0.5–0.99	7	24,000	110,000	930
	1.0–1.99	10	14,000	46,000	390
	2.0–3.4	7	9,300	46,000	390
	3.5–4.9	6	1,800	240,000[3]	23
	5.0[3]	10	14,200	240,000[3]	3.6
Great Neck Village	Unchlorinated	30[4]	23,000	—	—
	0.5–0.99	12	17	2,400	3.6
	1.0–1.4	9	15	930	<3.6
	1.4–1.9	14	23	430	<3.6
	2.0–2.4	7	3.6	290	<3.6
	2.5–2.9	8	5.5	23	<3.6
	3.0[3]	9	<3.6	93	<3.6
Lawrence	Unchlorinated	30	15,000,000	—	—
	1.5–3.9	13	750	240,000[3]	15
	4.0–4.9	28	43	240,000[3]	<3.6
	5.0[3]	18	3.6	110,000	<3.6

[1] Return sludge chlorinated.
[2] Return sludge not chlorinated.
[3] Or greater.
[4] Sewage prechlorinated, but not to a residual.

TABLE II.—Summary of Sewage Chlorination Study Results

Plant	Average before Chlorination					Chlorine Dose (p.p.m.)		Av. O.T. Residual Chlorine Range Required to Reduce Median M.P.N. Value to		
	B.O.D. 5-day (p.p.m.)	Susp. Sol. (p.p.m.)	Temp. (° C.)	pH	M.P.N. per 100 Ml.	During 24 Hr.	During Test Period	2,400	1,000	100
Coney Island	174.5	188.0	23.0	7.3	46,000,000	23.3	25.2	3.5–4.9	>5.0	>5.0
Lawrence	144.3	84.8	20.6	6.9	15,000,000	15.5	13.0	<1.5	1.5–4.0	4.0–5.0
Oyster Bay	91.6	77.9	17.8	6.3	24,000,000	—	9.7	<0.5	0.5–1.0	1.5–2.0
Jamaica	35.2	28.1	21.8	7.1	20,000,000	6.5	5.4	0.2–0.4	0.4–0.6	1.0–1.3
Great Neck	12.5	18.6	21.6	6.8	23,000[1]	12.3	10.8	<0.5	<0.5	0.5–1.0
Kings Park	6.1	31.2	23.5	7.4	93,000[2]	—	3.3	<0.5	<0.5	0.5–1.0

[1] Sewage prechlorinated. [2] Return sludge chlorinated.

each laboratory. Sampling was continued one day each week for 10 weeks. At every 2-hr. interval a sample of effluent before chlorination was also taken.

Residual chlorine was measured by the ortho-tolidine test. To provide uniformity and to permit the determination of residual chlorine values through a range from 0 to 5.0 p.p.m., standards in 2-oz. French square bottles were used. All standards, bottles, and ortho-tolidine reagent were supplied by the Division of Laboratories and Research. The residual chlorine was measured in a duplicate of the bacteriologic sample at the time the bacteriologic sample was dechlorinated.

The pH values of both the unchlorinated and chlorinated samples were determined at the time of sampling using either colorimetric or electrometric methods.

The bacteriologic examinations were confined to determination of the most probable number (M.P.N.) of coliform bacteria, using "Standard Methods" (1). Difco dehydrated media freshly prepared were employed by all laboratories. Three tubes each of a series of at least five decimal volumes of 1 ml. were examined. All tubes of all dilutions giving a positive presumptive test were confirmed by inoculation into brilliant-green lactose bile broth fermentation tubes.

Operating data, including the B.O.D. and solids values of the unchlorinated effluents, were obtained at each weekly test.

Results

The results of the bacteriologic examination of samples from each plant are given in Table I under various ranges of residual chlorine values.

A summary of the characteristics of the effluents chlorinated is given in Table II, together with the chlorine dose calculated from the weight of chlorine used during the day of the test and the test period. The average ortho-tolidine residual chlorine range in which reduction of the median M.P.N. per 100 ml. to values of 2,400, 1,000, and 100, respectively, has been taken from the results given in Table I. The various effluents are listed in the descending order of their strength as measured by the 5-day B.O.D. This order coincides with the concentration of suspended solids, except for that at Kings Park, which was affected by bulking during part of the test period. Also the descending order of chlorine used follows the B.O.D. order except at Great Neck, where excessive amounts of chlorine were employed.

The number of sewages examined is a rather small total from which to draw conclusions. It should be remembered that these are plant-scale tests, that no control of the mixing of chlo-

rine with the effluents was attempted, and that the established 15-min. contact period was variable.

The results do show that the same residual chlorine content as measured by the ortho-tolidine test in different sewage plant effluents does not effect a similar reduction in coliform density as measured by the median M.P.N.

The results suggest that in actual plant practice the amount of chlorine, measured by the ortho-tolidine residual, required for reduction of coliform density to a predetermined concentration measured by the median M.P.N., is dependent on the pretreatment of the sewage. Effluents from secondary treatment plants require less residual chlorine than do effluents from primary treatment plants. Raw sewage requires even more than primary plant effluent and it may not be practical to reduce the median M.P.N. of coliform bacteria in raw sewage to less than 2,400 per 100 ml. by chlorination.

A report of these results was made to the conference groups by the committee with the recommendation:

". . . that a request be made to the United States Public Health Service to undertake similar plant-scale investigations, that such proposed investigation would be to determine whether in actual plant practice the amount of residual chlorine, measured by the ortho-tolidine or some other simple test, required for the reduction of coliforms in the effluent to a pre-determined concentration is dependent on the degree of treatment of the sewage before chlorination, and whether the reduction of coliform density to a predetermined level in different plants of the same type or with the same degree of treatment before chlorination may be accomplished by the same level of residual chlorine."

The recommendation was adopted and such a request was made. However, because of prior commitments and budgetary limitations, the U. S. Public Health Service could not offer the assistance necessary.

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TWO STATES WORK OUT POLLUTION CONTROL PROGRAM FOR BOUNDARY WATER

A proposal stream classification program has been worked out by officials of Rhode Island and Connecticut for water pollution control on an interstate basis, according to the August, 1952, *News Letter* of the New England Interstate Water Pollution Control Commission. The stream involved is the Pawcatuck River, which forms the boundary between Rhode Island and Connecticut and drains 313 sq. mi. in the two states.

The classification program proposed for the river valley divides the Pawcatuck River and its tributary streams into some 40 sections. Pollution presently existing in each section is measured and the program specifies improvements that could be accomplished through treatment or elimination of industrial and domestic wastes.

The other states of the compact are studying the Pawcatuck "pilot plan" for ideas to incorporate in pollution control programs of their own.

EFFECTS OF USING LAGOONED SEWAGE EFFLUENT ON FARMLAND *

By Sam L. Warrington

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Sewage effluent from a lagoon or oxidation pond can be used successfully on some crops as irrigation water and may increase the yield per acre as much as 12.5 per cent and the nitrogen, phosphoric acid, and potash content 11 per cent in 6 months time. The statement sounds too good to be true, but the detrimental side of the picture has not been mentioned. Two of the detrimental effects are that (*a*) the harmful chemicals may be concentrated enough to ruin the land and (*b*) unless the effluent has been properly treated it may be the missing link in the spread of all waterborne diseases of the city.

The possibility that this water might spread diseases was the reason for making the study. For the experiment, it was decided to spend most of the time on the harmful rather than the beneficial effects.

This seemingly pessimistic attitude was taken in view of the fact that it has long been known that any organic waste eventually makes excellent fertilizer and is nature's own way of replenishing the soil. Thus, if the water will not ruin the soil or spread any diseases, it can be assumed that it will be of great value in these days of increasing water shortages.

After conferring with experienced farmers, soil specialists, and men from soil laboratories and experiment stations about what procedure should be followed in the study, the following conclusions were reached:

1. The degree of treatment and quality of the effluent should be considered.
2. The results would depend largely on the chemical composition of the water, the rainfall, the type of soil, the method of application, and the types of crops to be grown.
3. An actual yield per acre comparison would be necessary, water being only one of the many variables in plant growth.
4. The soil should be analyzed to determine the accumulation of total salts, sodium, pH, boron, nitrogen, phosphoric acid, and potash.

Two 10-acre plots of similar soil were selected for the experiment. The plots are adjacent to the Edinburg, Tex., sewage treatment plant, which gives complete treatment. Units of the plant include a primary clarifier, trickling filter, final clarifier, digester, sludge drying beds, and a 23-acre lagoon.

Lagoon Effluent Low in B.O.D.

The lagoon is about 3 ft. deep and allows a detention period of better than 30 days, depending on the industrial waste load. The lagoon system of restoring oxygen to the effluent through a vigorous algal growth is simplicity itself. The effectiveness of the lagoon is shown by the reduction in the M.P.N. of coliform bacteria from 1,100,000 to 450 per 100 ml. between inlet and outlet.

Another incident in favor of the lagoon happened at the peak of the tomato canning season and after a 4-in. rain. The flow volume was too large to permit any recirculation. Conse-

* Presented at 10th Annual Meeting, United States-Mexico Border Public Health Assn.; Monterrey, N. L., Mexico; March 24–27, 1952.

TABLE I.—Comparison of Chemical Analyses of Lagoon Effluent and Rio Grande River Water

Chemical	Lagoon Effluent	River Water
Total salts (p.p.m.)	1,050.00	800
Chloride (p.p.m.)	390	320
Calcium (p.p.m.)	40	80
Sulfate (p.p.m.)	250	216
Sodium (p.p.m.)	100	43
Nitrogen (p.p.m.)	11.1	3
Potassium (p.p.m.)	27.8	0
Phosphate (p.p.m.)	Trace	0
pH	8.7	7.9
Boron (p.p.m.)	0.55	0.17

quently, the B.O.D. of the final clarifier effluent, which normally runs less than 15 p.p.m., increased to 78 p.p.m. and was discharged into the lagoon. Later the B.O.D.'s on the effluent from the lagoon did not go above 3 p.p.m.

Comparison of Effluent and River Water

Chemical analyses of the Rio Grande River water and the lagoon effluent are compared in Figure 1. Comparative analyses of the two waters are given in more detail in Table I.

Analysis of the lagoon influent showed 35.7 p.p.m. nitrogen. In the colorimetric tests for nitrogen in the lagoon the algae had to be strained out, as a result of which no nitrogen was found in the sample. Presumably the nitrogen was fixed in the algae and was released later when the water was put on the soil. This theory was substantiated when two soils were examined later.

The beneficial factors of nitrogen, phosphorus, and potash in the soil increased roughly 11 per cent in the field using the effluent water. This increase was made by applying 12 in. (or three 4-in. waterings) during the 4-month growing period.

Due to the distinct alkalinity and potassium content of the lagoon water, the soil laboratory did not recommend its use more than twice yearly.

The pH of the lagoon effluent at the

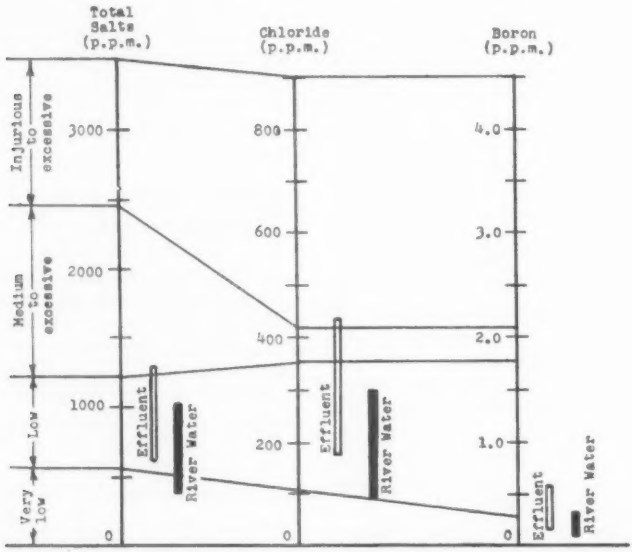

FIGURE 1.—Comparison of total salts, chlorides, and boron in lagoon effluent and Rio Grande River water.

TABLE II.—Chemical Concentrations in Test Soil Plots

Chemical	Concentration		
	Effluent (p.p.m.)	River (p.p.m.)	Increase (%)
Total salts	1,250	940	33.0
Chlorides	275	180	53.0
Phosphorus	190	165	11.5
Nitrates	250	225	11.1
Potash	34.4	31.8	11.1

time of sampling was very high and appeared to fluctuate with the temperature, daylight, and darkness. With a pH of 7.6 in the lagoon influent, the effluent value would go as high as 9.6 during bright sunny days and then fall back as low as 8.3 at night. This fluctuation seems to vary with the life cycle of the algae. At any rate, the peaks of the pH were "temporary" and did not raise the alkalinity of the soil enough to be of importance.

Test Plot Results

To determine the yield per acre, test cotton was grown. The yields were 2 bales per acre on the land irrigated with river water and 2.5 bales per acre on the land irrigated with the effluent. This 12.5 per cent increase in yield was due in part to the fact that the effluent water was available when needed. In other respects, the two crops were about the same. The cotton watered with effluent had a darker green color and more leaves. It also had to be chemically defoliated to stop the growth and allow the cotton to open up before the plow-up deadline. The young growth and undeveloped bolls were estimated at 0.5 bale per acre when the cotton was plowed under.

Near the end of the growing period analyses were made of the two soils. Table II gives the results and the increase of the soil constituents.

The total salts and chlorides increased 33.0 and 53.0 per cent, respectively. This increase seems to be the most harmful factor. The adverse effects of excess soluble salts on the properties of soils cannot be too strongly emphasized. The three principal factors causing the salt to build up—arid climate, poor drainage, and irrigation—are present in the valley area. For this reason, it is doubtful whether the benefits derived from applying the effluent will offset the increase in salts, which may eventually make the land less productive.

It should be pointed out, however, that the salts in the soil at present are very low due to artificial underdrains, and the percentage increase seems large because the initial value was small.

Soil colloids (that is, clay and organic matter) have the property of adsorbing the cations, such as sodium, calcium, and magnesium, upon their surfaces. Although these adsorbed cations are chemically combined with the colloid, they may be replaced by other cations occurring in the soil solution. Sodium may be the predominant cation in the original saline water to which the soil has been subjected, or it may become dominant in the soil solution due to the precipitation of calcium and magnesium compounds. Therefore, it should always be accounted for in a water analysis.

The soluble sodium percentage of water is an important index of its suitability for irrigation, because a

TABLE III.—Classification of Irrigation Waters with Respect to Boron

Classification	Boron (p.p.m.)	
	Sensitive Plants	Tolerant Plants
Excellent to good	<0.40	<1
Good to injurious	0.40 to 1	1 to 2
Injurious to unsatisfactory	>1	>2

TABLE IV.—Tolerance of Various Cultivated Plants to Boron[1]

Sensitive	Semitolerant	Tolerant	Sensitive	Semitolerant
Lemon	Lima bean	Carrot	Grape	Ragged robin
Grapefruit	Sweet potato	Lettuce	Apple	Rose
Avocado	Bell pepper	Cabbage	Pear	Radish
Orange	Tomato	Turnip	American elm	Sweet pea
Thornless blackberry	Pumpkin	Onion	Navy bean	Pima cotton
	Zinnia	Broadbean	Persian (English) walnut	Acala cotton
Apricot	Oat	Gladiolus		Sunflower (native)
Plum	Milo	Alfalfa	Black walnut	Canadian field pea
Prune	Corn	Garden beet	Pecan	
Peach	Wheat	Mangel		
Cherry	Barley	Sugar beet		
Persimmon	Olive	Palms		
Kadota fig				

[1] In each group the plants first named are considered as being more sensitive and the last named more tolerant.

high proportion of sodium in the water results in a high proportion of sodium in the soil solution. This has a marked effect on the exchange complex of the soil, with consequent adverse effects on the physical properties of the soil. Most authorities agree that if the soluble sodium percentage is less than 60, trouble from excess sodium will not usually occur. The effluent showed only 10 per cent; therefore, no noticeable difference in sodium content was noted in the soils.

Boron is another factor influencing water quality. Small but definite amounts of boron must be available either from irrigation water or soil to obtain good growth of crops, but toxic effects occur if more than traces of boron are present. From Table III it will be noted that the 0.55 p.p.m. given in Table I is considered fairly safe. Table IV gives the tolerance of various cultivated plants to boron.

Conclusions

From a public health standpoint, the degree of treatment and the types of crops grown should be of utmost importance. Where complete treatment is not practiced the city concerned should control the use of the effluent and the types of crops grown. It should be kept in mind that the proper disposal of the effluent should outweigh the value of the crops grown.

TABLE V.—Tolerance of Forage Crops to Salt

Good	Moderate	Poor
Alkali sacaton	White sweet clover	White Dutch clover
Salt grass	Yellow sweet clover	Meadow foxtail
Nuttall alkali grass	Perennial rye grass	Alsika clover
Bermuda grass	Barley (hay)	Red clover
Rhodes grass	Strawberry clover	Ladino clover
Rescue grass	Dallis grass	Burnet
Canada wild rye	Sudan grass	
Beardless wild rye	Hubam clover	
Western wheat grass	Alfalfa (Calif. common)	
	Tall fescue	
	Orchard grass	
	Tall meadow oat grass	
	Cicer milk vetch	

Crops which do not come in contact with the water may be grown with comparative safety.

In irrigated sections where salt naturally tends to build up, the water should be used with caution. If the effluent is used, the salts, particularly chlorides, should be checked often. Table V classifies some of the common forage crops according to their salt tolerance.

The fertilizing value of the effluent is great, and, when it can be used, the process can make an asset out of a liability.

Acknowledgments

The author acknowledges with thanks the assistance given him by R. A. Beers, city manager, Edinburg, Tex.; A. E. Potter, owner of the experimental land; G. R. Schultz, Texas Soil Laboratory, McAllen, Tex.; E. M. Kroth, soil chemist, Texas A & M Experiment Station, Weslaco, Tex.; B. J. Owen, water superintendent, Edinburg, Tex.; Cordell Edwards, soil chemist, Rio Farms, Monte Alto, Tex.; and W. N. Wells, chemist, Cannery Waste Research Project, Weslaco, Tex.

NPA WATER RESOURCES DIVISION CHANGES

The Water Resources Division of NPA, which handles the regulations on water supply and sewage projects and was a part of the Textile, Leather and Specialty Equipment Bureau, was transferred on September 12, 1952, to the Facilities and Construction Bureau. The latter bureau has over-all responsibility for coordinating and expediting all NPA functions relating to construction.

Also announced were proposed relaxations of construction regulations to become effective April 1, 1953. Under the proposed Direction 8 to CMP Regulation 6, projects of the water and sewage industry would be classified under "all other" construction projects and as such would be permitted to self-authorize quarterly allotments of up to 25 tons of steel (not to include more than 2½ tons of alloy steel and no stainless steel), 5,000 lb. of copper, and 2,000 lb. of aluminum for one project in a quarter.

Other actions in the Water Resources Division included resignation of Gerald E. Arnold, Director of the Division, to assume the position of Deputy Commissioner of Water, Philadelphia, Pa. He is succeeded as Director of the NPA Water Resources Division by James Crenshaw, who had been Administrative Assistant and who had previously been a member of the staff of the Water Division, War Production Board.

Industrial Wastes

NEUTRALIZATION OF ACID FELT PROCESSING WASTE*

By Russell G. Ludwig and Harvey F. Ludwig

Respectively, Consulting Sanitary Engineer, Ludwig Bros. Engineers, Alhambra, Calif., and Sanitary Engineer Director, U. S. Public Health Service, Washington, D. C.

Acid wastes constitute one of the most common types of troublesome industrial wastes being discharged to community sewer systems. Continued industrial expansion in Southern California has increased their magnitude, and correspondingly their deleterious effects, until in recent years regulations have been adopted by sewerage authorities which restrict the acidities of such discharges within reasonable limits.

The principal damage caused by the acid wastes has been attack and deterioration of cement-bonded sewer materials, such as brick mortar at manholes and also concrete sewer pipe. Even where these immediate signs of damage have been lacking, the wastes have been considered objectionable unless neutralized because of their effect in increasing sulfide production in the flowing sewage, particularly in the long flat trunk sewers common to the Los Angeles metropolitan area. Both the Los Angeles City and the Los Angeles County Sanitation Districts sewer systems serve to collect sewage from a large number of inland communities and to transport it long distances before final discharge to the ocean. The lengthy flow times occurring in the lower sections of these systems are generally productive of sulfides in varying degrees. Since these large sewers are constructed of concrete, the trunk sewer authorities, while anxious to render good service to industry, have found it necessary to ask the individual communities served to place reasonable restrictions on the acid content of the industrial discharges they receive. Although the determination of reasonable limitations is in itself a very complex question, the problem has been tentatively solved by the establishment of simple pH limitations. Generally the regulations require that the minimum pH of the industrial discharge be limited to 6.0.

In the present instance the wastes are produced by a felt manufacturing plant which discharges to the Alhambra municipal sewer system, and subsequently to the Los Angeles County Sanitation Districts system.

Nature of Wastes

The acid nature of the felt processing wastes is due to the sulfuric acid treatment employed to "shrink" the wool fibers; that is, to restore their natural "curl" as a part of the shrinking process. A preliminary washing tends to remove this curl, and restoration is necessary in order to develop a felt which has a high tensile strength (a high resistance to being pulled apart). Sulfuric acid is therefore essential to the processing operations.

To obtain basic information on the quantity, pH, and acidity of the wastes, measurements of these factors were made over two typical daily plant runs, from 7 AM to midnight. The plant is

* Presented at 1952 Annual Meeting, California Sewage Works Assn.; Santa Cruz, Calif.; April 23–26, 1952.

normally shut down from midnight to 7 AM. The flow measurements (Figure 1) were made by a V-notch weir installed in the last manhole of the plant's discharge sewer. Samples were collected at 30- to 45-min. intervals, and a composited sample prepared by adding portions together in proportion to the flow. At the laboratory the pH and acidity (or alkalinity) were determined for all samples. These data are shown in Figure 2. Acidity and alkalinity titrations were made to a pH end point of 6.0 rather than 4.3 to make the results more directly applicable to design.

The flow varies during the day over a wide range, the measured extremes being 0.05 to 2.3 cu. ft. per sec. However, the effective range during the working hours is roughly 0.2 to 1.0 cu. ft. per sec. The total daily flow averaged 146,000 gal., with a maximum hourly flow rate of 20,000 g.p.h.

The pH values varied from 0.9 to 8.6 and were predominately acid. Changes in pH were rapid; for example, on one morning the pH fell from 6.7 to 1.4 in 30 min. From the point of view of design, the principal factor is the total weight of acidity which must be neutralized, as this determines the amount of alkali which must be added to maintain the designated minimum pH in the effluent discharged to the sewer. Acidity rates computed from the data shown in Figures 1 and 2 ranged from 0 upward to 200 lb. per hr. Average rate over the working day was estimated to fall between 25 and 40 lb. per hr. Using soda ash as the neutralizing chemical, the total daily use was estimated to be from 300 to 500 lb.

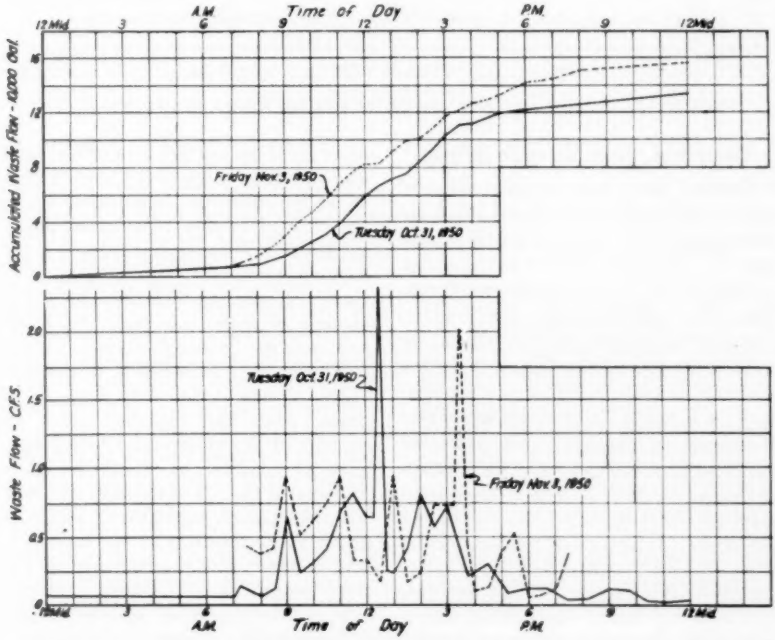

FIGURE 1.—Flow measurement diagrams for acid felt wastes on two typical days.

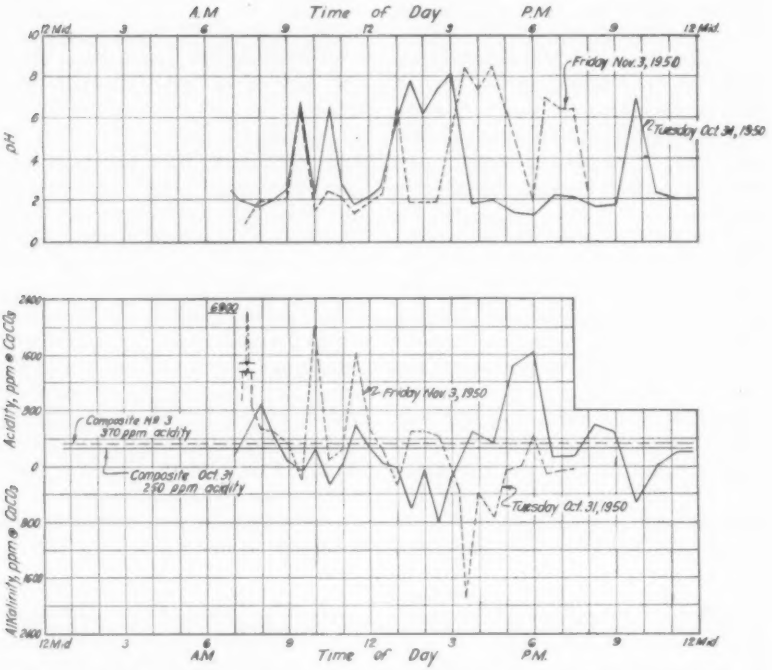

FIGURE 2.—Acidity, alkalinity, and pH of acid felt wastes on two typical days.

Design of Neutralization Works

Despite the common occurrence of acid neutralization problems, there are surprisingly few reports in the literature to assist the engineer in designing a system to meet a particular problem. The problem is essentially to determine how much storage should be provided. The ideal solution, from the point of view of providing positive control, is a batch system involving two chambers, so that the waste collected in one of the chambers may be neutralized and discharged while the incoming flow is being diverted to the second chamber. However, for large plants utilizing large quantities of water, this requires excessive storage volumes, and also too much operational labor, especially if storage volumes are too small. Storage capacities in this case must be large enough to permit handling the maximum flows and also to allow for collection of the flow during the off-work hours. The more practical solution in many instances is a continuous automatic system which includes a reaction chamber providing enough retention so that the added neutralizing chemical may be mixed and permitted to react to a sufficient degree of completion before the liquid passes from the chamber, with the amount of chemical added being regulated as indicated by continuous measurement of the pH of the effluent. Such a control system regulates chemical addition in proportion to the weight of acid received into the chamber in unit time, regardless of variations in flow and concentration of acidity. Such systems reduce operation costs to a minimum, as only routine maintenance

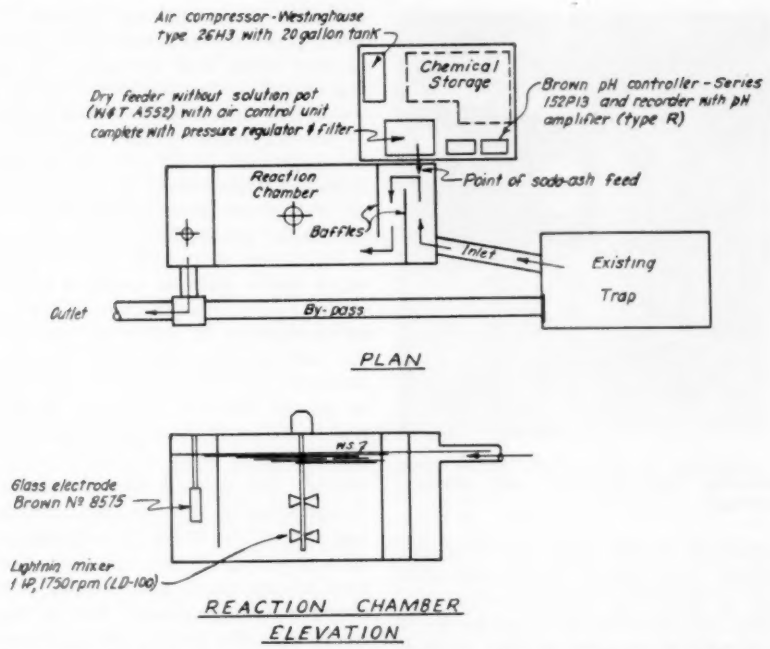
Air compressor - Westinghouse type 26H3 with 20 gallon tank
Chemical Storage
Brown pH controller - Series 152P13 and recorder with pH amplifier (type R)
Dry feeder without solution pot (W & T A552) with air control unit complete with pressure regulator & filter
Reaction Chamber
Point of soda-ash feed
Baffles
Inlet
Existing Trap
Outlet
By-pass
PLAN
Glass electrode Brown Nº 8575
Lightnin mixer 1 HP, 1750 rpm (LD-100)
REACTION CHAMBER ELEVATION

FIGURE 3.—Schematic layout of acid felt wastes neutralization works, Standard Felt Co., Alhambra, Calif.

is required. To be successful a continuous neutralization system must provide a proper relationship between the period of retention and amount of mixing provided by the reaction chamber as compared with variations in the influent acidity load. Otherwise the response of the effluent pH indicator will not be sufficiently correlated with variations in influent acidity to permit proper control of the rate of chemical feeding. The smoothing-out action of the reaction chamber in effect prevents development of a "hunting" condition in the control system. Where final pH control is desired to be maintained within close limits, an additional prestorage chamber may be necessary, particularly where flow and pH variation is extreme.

The actual design provided in this instance is illustrated by Figures 3, 4, and 5. The reaction tank, built of redwood, has a capacity of 5,000 gal Rapid mixing is provided by a 1,750-r.p.m. mixer with neoprene covered shaft and propeller. The neutralizing

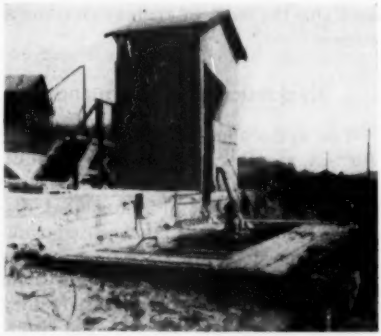

FIGURE 4.—Control house and neutralizing chamber for acid felt wastes.

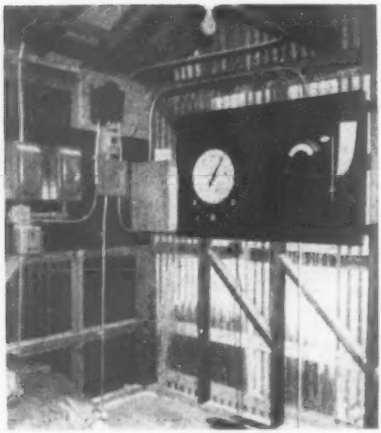

FIGURE 5.—Interior of control house showing pH recorders and chemical storage.

chemical is soda ash, fed by a dry feeder. The rate of feed is controlled by an electronic pH controller with glass pH electrode; the feed system is activated by compressed air. A sheet metal building was constructed to house the feeder and pH equipment controls (including a continuous pH recorder) and also to provide room for storage of chemicals. The installation was completed in the fall of 1951 at a cost of approximately $5,000. This included the building and reaction chamber and all necessary equipment, and also the work of rearranging sewer connections.

Evaluation of Performance

The system has now been operating for six months, long enough to indicate the efficiency of the design. Over this period the pH of the effluent discharged to the sewer has been continuously recorded, and a review of the record charts indicates that the system as designed is producing a satisfactory effluent essentially all of the time. There have been, however, a few instances when the effluent pH decreased to values less than that desired for short periods, corresponding to times of very heavy acid discharge. These few exceptions are not believed to represent any significant corrosion hazard to the municipal system, considering the additional smoothing-out or buffering obtained when the treated industrial waste becomes diluted with the normal sewage flow.

The study of the pH records indicated that a reaction chamber of approximately double the size of the existing chamber, or, better, two units of the existing type operating in series, would be needed if it were required to provide absolute insurance against any lowering of the effluent pH below 6.0 and that such a design would scarcely be economically justifiable. One practicable measure that could be taken would be to install a limestone-chip type trap in the line from that area of the plant where heavy acid discharges are produced. Such a trap would take the "edge" off the heavy acid discharges, and hence would assist appreciably in smoothing out the acidity before the wastes reach the reaction chamber. Since limestone chips are cheaper than soda ash, the over-all cost of chemicals would not be increased. The principal difficulty is the initial cost of construction.

Accumulated operating experience to date has indicated a few other conclusions of value, as follows:

1. The point of chemical feed preferably should be located at the influent discharge to the reaction chamber to take advantage of this opportunity for mixing.

2. The mixer propeller should be of non-clogging design if necessary; in this case the waste, although previously subjected to gravity trapping, contains occasional stringy materials, which tend to become fouled in the propeller and disturb its dynamic balance.

3. The design should provide for ready removal of the mixer, in the event maintenance is required.

4. The automatic controls should provide for complete shutoff of the feeder when the influent pH is at or near the desired effluent pH.

5. A coarse-mesh wire basket should be placed over the feeder hopper to prevent pieces of paper and other miscellaneous materials from entering the feeder mechanism.

6. The glass electrode needs to be periodically inspected (every two or three days) to remove accumulated scum.

7. The over-all maintenance required by the system can be readily provided by one of the regular plant personnel.

INDUSTRIAL WASTE INVENTORY PROGRESS REPORT

In a progress report covering the 18-month period ending June, 1951, the Interstate Sanitation Commission has covered the activity and findings of its Industrial Waste Inventory in the area served by the Commission. This area includes New York Harbor and the adjacent waters of Long Island Sound, the Hudson River, and the Atlantic Ocean, with a total waste contributing population of about 11,000,000. The report contains 36 pages, plus 19 figures, 10 tables, and a detailed appendix on contributed wastes, by waterways.

Of the approximately 1,500 plants visited, 306 dispose of their waterborne wastes directly to District waters. The remainder either do not produce contaminating wastes, or dispose of them through public sewers. The heaviest concentration of plants contributing contamination directly is along the relatively short coastline of western Long Island. Other areas of concentration border Bridgeport (Conn.) Harbor and the waters around Staten Island.

Approximately 515 m.g.d. of contaminated water are discharged directly by the 306 plants. Some degree of treatment before discharge is provided by 138 plants for 433 m.g.d. Union County, N. J., alone discharges more than 40 per cent of the total volume. No direct industrial waste discharges are generated in New York County (Manhattan). Of the 515 m.g.d., approximately 65 per cent is discharged by the petroleum industry, 14 per cent by utilities, and 10 per cent by chemical industries.

In addition, 1,160 m.g.d. of uncontaminated flow are discharged directly to District waters. More than 90 per cent of the 1,675-m.g.d. total discharged to these waters is salt water obtained from the same source.

The survey results indicate that the food, utilities, chemical, and petroleum industries are the major sources of oxygen depleting wastes. Maximum potential loadings on District waters include 358,000 lb. of suspended solids, 10 tons of nonferrous metals, 18 tons of ferrous metals, 48 tons of acids, 3,600 lb. of cyanides, and 6,000 lb. of phenolic compounds. In addition, about 50 tons of fats, grease, and oils may be discharged daily.

COLORIMETRIC DETERMINATION OF CYANIDE, CYANATE, AND THIOCYANATE IN SEWAGE AND PLATING WASTES

By J. M. Kruse and M. G. Mellon

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In a recent paper (3) methods for the determination of complex cyanides and for cyanide in the presence of thiocyanate have been described. These methods, however, are unnecessarily complicated for cyanide in the absence of cyanide complexes and thiocyanate. In this paper, therefore, a simplified procedure is given for the determination of cyanide alone. This procedure is applicable when thiocyanate is absent and only free cyanide is to be determined. In addition, procedures for the determination of cyanate and thiocyanate are proposed.

Thiocyanate and cyanate are both intermediates in the decomposition of cyanide. Also, both these ions may be found in plating wastes and as intermediates or side products of reactions. For these reasons methods for the determination of these ions appear desirable.

For the macro determination of both thiocyanate and cyanate several useful methods are known. Among these are the use of silver nitrate for the titration of both thiocyanate and cyanate; the use of iron, mercury, and cobalt to form colored complexes with thiocyanate; and the use of a copper-pyridine system (8) for the colorimetric determination of cyanate. In addition, the pyridine-benzidine (1) and pyridine-pyrazolone (2) reagents have been shown to be applicable to a thiocyanate concentration of less than 1 p.p.m.

Of the methods mentioned only the pyridine-benzidine and pyridine-pyrazolone systems have the desired sensitivity of 0.1 to 10 p.p.m. Unfortunately, these two methods suffer from the disadvantages of unstable color systems, unstable reagents, and considerable time requirement for color development. Also, cyanide will interfere. In the case of cyanate, no method more sensitive than 50 p.p.m. could be found in the literature. For these reasons, new methods for the determination of thiocyanate and cyanate were developed.

Thiocyanate is determined with a copper-pyridine reagent. Although a similar system had been used for this determination by Spacu (7), the maximum sensitivity previously attained was 20 p.p.m. The present method is sensitive to less than 0.5 p.p.m. thiocyanate, and by boiling the sample the sensitivity can be increased still further.

The only interferences are iodide, mercury, and more than 10 p.p.m. of cyanide, complex cyanides, or nickel. The iodide can be removed with carbon tetrachloride in the form of iodine; the cyanide or complex cyanides can be removed by boiling of the sample. The cations can be removed by means of ion exchange or by precipitation of the hydroxides. More than 50 p.p.m. of magnesium also will interfere, but it can be removed in the same manner.

Cyanate is determined with a pyridine-pyrazolone reagent. Although this is the same reagent used for the determination of cyanide and thiocyanate, the conditions for the cyanate color development are quite different. The color is formed very rapidly and

is stable for several hours. The interferences are silver, copper, zinc, and ammonia, and, of course, thiocyanate and cyanide. All of the cations are removed by ion exchange. Actually, the color formed by ammonia is so intense that the reaction has been used as a basis for a new method of determining ammonia (4).

Determination of Cyanide

The cyanide sample is buffered at pH 6.8 and the color is then developed directly in the sample with the pyridine-pyrazolone reagent. The color system follows Beer's law for 0.04 to 2 p.p.m. cyanide and is stable for about 1 hr. after a period of color development.

1. Apparatus

1.1. Spectrophotometer, or photoelectric filter photometer transmitting at 620 mμ.

1.2. Volumetric flasks, 50-ml.

2. Reagents

2.1. Buffer solution, pH 6.8. Add 9.0 g. of KH_2PO_4 and enough $Na_2HPO_4 \cdot 2H_2O$ (about 11.8 g.) to give a pH of 6.8 to 900 ml. of water. Dilute to 1 l.

2.2. Chloramine-T, 1 per cent. Dissolve 0.20 g. of chloramine-T in 20 ml. of water. The solution should be freshly prepared each day.

2.3. 3-Methyl-1-phenyl-5-pyrazolone. The pyrazolone is recrystallized twice from 95 per cent ethanol, and can then be stored for months in a dark bottle.

2.4. Bis-(3-methyl-1-phenyl-5-pyrazolone). Dissolve 17.4 g. of recrystallized 3-methyl-1-phenyl-5-pyrazolone in 100 ml. of 95 per cent ethanol, add 25 g. phenylhydrazine, and reflux. Filter off the insoluble product, which is the bis-pyrazolone, at intervals of a few hours, returning the hot filtrate for further refluxing. The reaction may be continued for several days and a yield of more than 60 per cent obtained. Wash the bis-pyrazolone with several portions of hot 95 per cent ethanol. It may then be stored for months.

2.5. Pyridine-pyrazolone reagent. Dissolve 0.63 g. of recrystallized 3-methyl-1-phenyl-5-pyrazolone in 250 ml. of water by heating the mixture to about 75° C. and stirring while it cools to room temperature. To this solution add 50 ml. of redistilled pyridine containing 0.050 g. of the bis-pyrazolone. The bis-pyrazolone will dissolve in the pyridine in about 50 min. The pyridine solution should be freshly prepared, and the solutions should be mixed only shortly before use. The aqueous pyrazolone solution may be stored for 48 hr.

2.6. Standard cyanide solution. Dissolve 2 g. of cp. sodium cyanide in 1 l. of solution. This solution is then standardized by titrating with 0.05 *N* standard silver nitrate according to the Liebig method, using ammonium hydroxide and potassium iodide to indicate the end point. The standard solution is prepared from this solution by 500-fold dilution.

2.7. Water. Distilled water is needed for the preparation of the reagent and dilutions.

3. Procedure

3.0. Preparation of the standard curve. Dilute 0.5-, 1-, 2-, 5-, 10-, and 20-ml. aliquots of the standard solution to 20 ml. in 50-ml. volumetric flasks. To each add 10 ml. of buffer (2.1), 0.3 ml. of 1 per cent chloramine-T, stopper the flask, and shake; after 60 sec. add 15 ml. of the pyridine-pyrazolone reagent, dilute to 50 ml., and mix. After 30 min. (for color development), measure the absorbency at 620 mμ. Plot milligrams of cyanide *vs.* absorbency.

3.1. Analysis of the sample. Adjust the sample to pH 6 to 8 with a minimum of strong acid or base. Filter the sample to remove silt and insoluble material. Transfer a 20-ml. aliquot to a 50-ml. volumetric flask, and add 10 ml. of buffer (2.1). Add 0.3 ml. of 1 per cent chloramine-T, stopper the

flask, and shake; after 60 sec. add 15 ml. of the pyridine-pyrazolone reagent, dilute to 50 ml., and mix. After 30 min., measure the absorbency at 620 mμ. From the standard curve determine the amount of cyanide present in the original sample.

$$\text{p.p.m. CN} = \text{mg. CN} \times 50$$

Determination of Thiocyanate

Thiocyanate is determined in sewage and wastes by the formation of a dipyridine-copper(II)-thiocyanate complex, which is yellow when extracted with chloroform. Cyanide can be removed by boiling. If interfering cations are present, they are removed by passing the solution through a cation exchange column. The color formed is stable and can be measured immediately.

1. Apparatus

1.1. Spectrophotometer, or photoelectric filter photometer transmitting at 410 mμ.

1.2. Cation exchange column. The column can be constructed from a piece of 16-mm. tubing constricted at one end and fitted with a stopcock or a piece of Tygon tubing with a pinch-clamp and tip. The column should be about 40 cm. high and packed to a height of 20 cm. with resin. These dimensions, however, are only suggestions and are not critical.

1.3. Separatory funnel, 125-ml.

1.4. Volumetric flask, 25-ml.

2. Reagents

2.1. Amberlite IR 100–H cation exchange resin. This resin is used in the exchange column. It can be regenerated with 10 per cent sulfuric acid. Similar resins which retain mercury, nickel, and magnesium may be used in place of this resin.

2.2. Carbon tetrachloride, cp.

2.3. Chloroform, cp. The chloroform used in the procedure may be purified by extracting it first with two portions of 5 per cent sodium hydroxide and then with one portion of 10 per cent sulfuric acid. The chloroform layer is then drawn off and distilled for re-use.

2.4. Copper sulfate, 20 per cent. Dissolve 20 g. $CuSO_4 \cdot 5H_2O$ in 80 ml. of water.

2.5. Cotton.

2.6. Pyridine.

2.7. Standard thiocyanate solution. Dissolve 1.7 g. of potassium thiocyanate in 1 l. of solution. Standardize this solution by using it to titrate 0.12 g. silver nitrate, using ferric chloride to detect the end point. The standard solution is prepared from this solution by 100-fold dilution.

2.8. Water. Distilled water is used for all operations in the procedure.

3. Procedure

3.0. Preparation of the standard curve. Dilute 5-, 10-, 20-, 30-, 50-, 100-, 150-, and 200-ml. aliquots of the standard solution to 250 ml. and pass the solutions through the cation exchange column. Discard the first 75 to 100 ml. of effluent, and then transfer a 100-ml. aliquot of the subsequent effluent to a 125-ml. separatory funnel. Treat as described in 3.3.

A separate calibration curve is needed for the simplified procedure, which may be used if no interfering cations are present. For this curve, transfer 2.5-, 5-, 10-, 20-, 50-, 75-, and 100-ml. aliquots of the standard solution to 125-ml. separatory funnels, dilute to 100 ($\pm$ 3) ml., and treat as described in 3.3. Measure the color at 410 mμ. and plot milligrams thiocyanate *vs.* absorbency.

3.1. Analysis of the sample. Filter the sample to remove silt and insoluble materials. If no interfering cations are present, measure out a 100-ml. aliquot, adjust the pH to 2.5 to 4 with dilute sulfuric acid or sodium hydroxide, and proceed as described in 3.2.

If interfering cations are present, pass the sample through the ion exchange column. Discard the first 75 to 100 ml. and then use the next 100

ml. of effluent. Wash the column with about 100 ml. of water to prepare it for the next determination. The rate of flow through the column should be 1 to 2 drops per second. In case no cation exchange column is available, it is possible to remove the interfering cations by adjusting the acidity to about pH 11 and filtering off the hydroxides. A double filtration, first through a fast and then through a fine filter paper, is required to remove all of the insoluble hydroxides. If possible, however, an exchange column should be used.

3.2. Adjust the acidity of the effluent to pH 2.5 to 4 with dilute sulfuric acid or sodium hydroxide. If no cyanide or complex cyanides are present, transfer the sample to a 125-ml. separatory funnel and proceed as in 3.3. If cyanides are present, boil the solution for about 15 min. Allow the solution to cool, transfer it to a 125-ml. separatory funnel and bring the total volume to 100 ($\pm$ 3) ml. By marking this volume on the separatory funnel in advance, the required volume can be easily attained.

3.3. Add 2.5 ml. of carbon tetrachloride to the sample and shake the mixture. Allow the phases to separate and drain off and discard the carbon tetrachloride. Add 1.5 to 2 ml. of the 20 per cent copper sulfate solution and about 4 ml. of pyridine. Shake the solution. Add 20 ml. of chloroform and thoroughly shake the solution. Drain the chloroform through a small cotton plug into a 25-ml. volumetric flask. The cotton plug serves to filter out water from the chloroform. Add 5 ml. of fresh chloroform to the sample, shake, and drain the chloroform through the cotton plug into the volumetric flask until the total volume of 25 ml. is attained.

3.4. Measure the absorbency or transmittance of the chloroform layer at a wave length of 410 mμ. with a spectrophotometer. In case a filter photometer is used, select a filter having a peak transmittance as close to 410 mμ. as possible, even though the solution may appear green rather than yellow. From the standard curve obtain the amount of thiocyanate in the sample, and from this calculate the thiocyanate concentration in the original sample.

$$\text{p.p.m. SCN} = \frac{\text{mg. SCN} \times 10{,}000}{\text{ml. sample}}$$

3.5. Note: If the original sample contained less than 0.5 p.p.m. thiocyanate, a larger sample should be used in 3.1. Collect a large enough amount of effluent from the columns to contain at least 0.5 mg. thiocyanate. Boil the solution in step 3.2 until the volume is less than 100 ml., and then proceed as described.

Determination of Cyanate

Cyanate ion in the concentration range of 0.1 to 10 p.p.m. forms a color with the pyridine-pyrazolone reagent in weakly acidic solutions. However, ammonia also forms this color under the same experimental conditions, so the removal of ammonia prior to the determination of cyanate is necessary. This separation is accomplished by passing the sample through a cation resin to retain the ammonia. The column should operate on the sodium cycle, as strongly acidic resins will decompose cyanate.

Thiocyanate and cyanide will also produce colors with the reagent. However, by extracting the aqueous solution in which the color had been formed with carbon tetrachloride, the relative intensity of the cyanate color is greatly enhanced while that of the thiocyanate and cyanide is decreased. A two-component analysis is sometimes possible. If less than 0.25 p.p.m. of cyanide or thiocyanate are present, their interference becomes negligible.

The cyanate solution is then treated with a 3 per cent solution of chloramine-T to convert the cyanate to ammonia or some intermediate compound

which is also formed by adding the pyridine-pyrazolone reagent. Color development is complete in less than 60 sec. The solution is then extracted with carbon tetrachloride to increase the sensitivity of the method for cyanate. In carbon tetrachloride the color is stable for several hours.

1. Apparatus

1.1. Spectrophotometer, or photoelectric filter photometer transmitting at 450 mμ.

1.2. Cation exchange column. The column can be constructed from a piece of 22-mm. tubing constricted at one end and fitted with a stopcock or a piece of Tygon tubing with a pinch-clamp and tip. The column should be about 40 cm. high and packed to a height of 20 cm. with resin. All of the dimensions may be changed, however.

The resin should be of the sulfuric acid or polystyrene type and operate on the sodium cycle. Resins that have been found satisfactory are Amberlite IR 100–H, IR 120, Dowex-50, and Illco C–211. The acid resins may be converted readily to the sodium cycle by passing a sodium chloride solution containing some sodium hydroxide through the column until the effluent is alkaline. After washing with water, the column is ready for use. The column should be checked occasionally for break-through of ammonia. (Columns in use in this laboratory are still satisfactory after more than 100 determinations.)

1.3. Separatory funnels, 125-ml.

1.4. Transfer pipette, 1-ml., graduated.

2. Reagents

2.1. Buffer solution, pH 3.7. To 45 ml. 10 per cent sodium acetate in 440 ml. of water add enough concentrated acetic acid to give a pH of 3.7.

2.2. Carbon tetrachloride, cp. The carbon tetrachloride used in the procedure may be purified by distillation.

2.3. Chloramine-T, 3 per cent. Dissolve 0.6 g. of chloramine-T in 20 ml. of water.

2.4. 3-Methyl-1-phenyl-5-pyrazolone. The pyrazolone is recrystallized twice from 95 per cent ethanol, and can then be stored for months in a dark bottle.

2.5. Bis-(3-methyl-1-phenyl-5-pyrazolone). Dissolve 17.4 g. of the recrystallized 3-methyl-1-phenyl-5-pyrazolone in 100 ml. of 95 per cent ethanol, add 25 g. phenylhydrazine, and reflux. Filter off the insoluble product, which is the bis-pyrazolone, at intervals of a few hours, returning the hot filtrate for further refluxing. The reaction may be continued for several days and a yield of more than 60 per cent obtained. Wash this bis-pyrazolone with several portions of hot 95 per cent ethanol. It may then be stored for months.

2.6. Pyridine-pyrazolone reagent. Dissolve 0.63 g. of recrystallized 3-methyl-1-phenyl-5-pyrazolone in 250 ml. of water by heating the mixture to about 75° C. and stirring while it cools to room temperature. To this solution add 50 ml. of redistilled pyridine containing 0.050 g. of the bis-pyrazolone. The bis-pyrazolone will dissolve in the pyridine in about 50 min. The pyridine solution should be freshly prepared and the solution should be mixed only shortly before use. The aqueous pyrazolone solution may be stored for two or three days.

2.7. Standard cyanate solution. Dissolve 2 g. of potassium cyanate in 1 l. of solution, and standardize by titration with silver nitrate (5)(6). The standard solution is prepared from this solution by 200-fold dilution, and should be made slightly alkaline. This standard solution is stable for about one week.

2.8. Water. Distilled water is needed for the preparation of the reagent and dilution.

3. Procedure

3.0. Preparation of the standard curve. Dilute 1-, 2-, 5-, 10-, 25-, and 50-ml. aliquots of the standard solution

to about 50 ml. in 125-ml. separatory funnels, and treat by the procedure described in 3.2. Plot milligrams of cyanate *vs.* absorbency.

3.1. Analysis of the sample. Filter the sample to remove solids, and then pass the sample through the ion exchange column. Discard the forerun (75 to 100 ml.) and then collect the next 50 to 60 ml. Transfer 50 ml. to a separatory funnel. Wash the ion exchange column with distilled water to prepare it for the next sample.

3.2. Adjust the pH of the sample to approximately 3.7 with acetic acid. Add 10 ml. of buffer (2.1) to the sample and mix the solutions. Add 0.9 ml. of 3 per cent chloramine-T. Stopper and shake the funnel. Add 30 ml. of the pyridine-pyrazolone reagent 90 sec. after the addition of the chloramine-T, and again shake the funnel. After 150 sec., extract the color with carbon tetrachloride. If thiocyanate or cyanide are absent, this time interval is not critical and either 25 or 50 ml. of carbon tetrachloride may be used for the extraction. If the color of the aqueous phase before extraction is only a pale purple, 25 ml. of carbon tetrachloride should be used; otherwise, use 50 ml. The carbon tetrachloride should be measured into volumetric flasks.

3.3 Measure the absorbency of the sample at 450 mμ. and obtain the amount of cyanate present from the standard curve. A reagent blank has to be tested with each set of determinations, and the absorbency of the blank subtracted from the measured absorbency.

$$\text{p.p.m. OCN} = \frac{\text{mg. OCN}}{2.5} \times \text{ml. } CCl_4 \text{ used}$$

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CORRECTION

On pages 1013 and 1014 of the August, 1952, issue of THIS JOURNAL, the cuts for Figures 9 and 10 should be interchanged.

DETERMINATION OF NAPHTHALENE IN INDUSTRIAL WASTES

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With the enormous growth of chemical industries in the past 50 years and the ever-increasing expansion, a corresponding need for the mitigation of the effects of industrial trade wastes has arisen. Harmful constituents may still go into bodies of water that serve municipal, industrial, agricultural, or recreational purposes. There are, in many cases, no suitable analytical methods for such constituents available for measuring the extent of pollution or the effects upon the various uses of the waters.

Naphthalene fell into this category. According to Gollmar (1) it was toxic to aquatic life at concentrations of 5 p.p.m. There was no satisfactory method of analyzing for such small quantities. Available methods for analyzing naphthalene in gases are either unreliable or inadequate to determine quantities much less than 1 per cent (10,000 p.p.m.) naphthalene. A few investigators attempted to determine naphthalene in a liquid phase, but again the methods were not too reliable and also were not selective, as they gave the same results for other hydrocarbons.

After numerous unsuccessful attempts to analyze naphthalene (by the production of fluorescein through the oxidation of naphthalene, formation of naphthaquinone, nitration, and sulfonation) a successful method was determined. This method is based on a reaction described by Schwartz (2), who in 1881 said that a very intense greenish-blue color developed on the addition of anhydrous aluminum chloride to a chloroform solution of naphthalene. The reaction was

$$AlCl_3 + C_{10}H_8 \xrightarrow{CHCl_3} C_{14}H_{10}\ (?)$$

Although Honig and Berger (3), also Homer (4), later disputed both the color and the final reaction product, there was a definite color formation.

The final color secured through experimentation varied from a light to deep blue (or bluish-purple) depending on the quantity of naphthalene present. The method was found to be applicable from 0.2 to 200 p.p.m. and in this range the accuracy was ± 5.6 per cent. The test can be extended down to 0.1 p.p.m. but the inaccuracy increases to a large degree. Below an extracted amount of 0.020 mg. of naphthalene in the test, difficulty was encountered in visibly detecting the blue color, and even with the aid of the spectrophotometer the inaccuracy of the determination increased. Above about 0.225 mg. the blue color was too intense and gave an inaccurate reading in the spectrophotometer.

Equipment and Materials

The equipment necessary is relatively simple. Separatory funnels, pipettes, 1-in. funnels, a 10-ml. mixing cylinder, a stop watch, and a centrifuge are required. A small weighing bottle, etched at the 7-ml. mark, fitted with a ground glass stopper, a mechanical shaker for shaking the weighing bottle, and a Fisher electrophotometer or Beckman DU spectrophotometer are also used.

The chemicals generally required are anhydrous aluminum chloride, c.p. chloroform, 1 per cent sodium hydroxide solution and alumina (preferably of 80- to 200-mesh). Naphthalene is required only for the preparation of standards. If sulfides are present in the waters to be analyzed, then a 10 per cent silver nitrate and a 10 per cent sodium hydroxide solution are also required.

Experimental Procedure

A selected aliquot of the naphthalene solution, previously filtered if any solid materials were present, was pipetted into a separatory funnel. Into this same separatory funnel were pipetted 5 ml. of 1 per cent sodium hydroxide and 5 ml. of c.p. chloroform. The contents were then shaken for 1 min. and allowed to settle for about another minute to enable good separation of the resulting two layers. The chloroform (lower) layer was then drained into a mixing cylinder previously filled to the 1-ml. mark with alumina. Care should be taken to admit as little water as possible into the mixing cylinder when draining the chloroform layer. Another 5 ml. of chloroform was added to the separatory funnel and the same procedure was repeated. Usually, due to slight solubilities of chloroform and also due to possible evaporation losses, only about 9.6 ml. of chloroform was recovered.

After shaking the mixing cylinder for 1 min., it was allowed to stand for another minute so that the alumina could settle to the bottom. Seven ml. of the chloroform solution was then carefully filtered through a 1-in. funnel into the clean, dry weighing bottle. To aid in speedy filtration, the filter paper is slightly wetted with chloroform. (No more than 0.5 to 1 ml. was used to wet the paper, and the funnel and the filter paper were shaken before pouring the chloroform-naphthalene solution onto the funnel.)

About 0.4 g. of anhydrous aluminum chloride was added, and the weighing bottle was immediately put on a mechanical shaker. After 2 to 3 min., the chloroform solution became blue or bluish-purple, the intensity of the color being proportional to the amount of naphthalene present.

The weighing bottle was removed from the shaker, the stopper removed, and the bottle allowed to stand for exactly 3 min. Five to six ml. of this solution were decanted into a 15-ml. centrifuge tube and centrifuged for 1 min. Care was taken in decanting so as not to disturb the solid particles on the bottom of the tube.

Four ml. of the centrifuged solution was then again decanted into a dry photocell. This photocell was placed either in a Fisher electrophotometer using a 525-mμ. filter or in a spectrophotometer and measured at 545 mμ. The concentration of naphthalene in p.p.m. was calculable either from an equation given later or from comparison with a standard plot.

Variables

As in most analytical methods, numerous variables had to be determined before a successful procedure was attained. When water droplets appeared in the final chloroform solution, instead of the blue color forming on the addition of the anhydrous aluminum chloride, the reaction would either remain colorless or become light blue. The presence of this water resulted in the formation of hydrochloric acid when the anyhdrous aluminum chloride was added—that is,

$$AlCl_3 + 3H_2O \longrightarrow 3HCl + Al(OH)_3$$

To prevent such water interference, the weighing bottles, absorption cells, mixing cylinder, centrifuge tubes, and funnels were carefully dried. To further dry the chloroform solution, however, alumina having a mesh size of 80 to 200 was added.

In the operation of by-product coke oven plants, a large amount of phenol

is usually produced. As this analytical method will be used on the effluents of coke oven plants, phenol interference was investigated. Experiments indicated that phenol did not affect the reaction of anhydrous aluminum chloride on naphthalene. One per cent sodium hydroxide was added, however, to prevent the phenols being extracted in the chloroform layer.

Because of the similarity of structure and of the reactions between anthracene and naphthalene, effects of anthracene were also investigated. Results showed that anthracene does not affect the reaction of aluminum chloride on naphthalene.

The time to develop the color fully and the quantity of anhydrous aluminum chloride required were experimentally determined. Aliquots of different concentrations of naphthalene were selected and analyzed in the usual manner, with the exception that the time of shaking was varied from 0 to 10 min. In the interval of 3.5 to 6.0 min., the specific per cent transmission of each sample remained relatively constant. For the purpose of standardization, however, the time of shaking was held to 5 min.

To determine the necessary amount of anhydrous aluminum chloride, identical samples of a naphthalene solution were again analyzed in the usual manner, but in this case the quantity of the aluminum chloride added for each analysis was varied. After the addition of 0.25 g. the values were constant within the experimental accuracy of the over-all test. In order to select a basis for comparison, 0.4 g. aluminum chloride was added.

When sulfides were present in the waters to be analyzed, a yellow to green to deep bluish-green appeared on the addition of the aluminum chloride to the naphthalene-chloroform solution. A modified method was devised to remove sulfides. This removal was performed by adding 10 ml. of a 10 per cent silver nitrate solution to the original aliquot, filtering, adding 10 ml. of 10 per cent sodium hydroxide, and refiltering into a separatory funnel. The usual procedure of analysis was then employed after omitting the step in which 5 ml. of 1 per cent sodium hydroxide was added to the separatory funnel.

Frequency Determination

In order to find the optimum frequency for the determination of naphthalene, an absorption curve was determined. The range covered was from 355 to 1,000 mμ. Inasmuch as the determination of an entire absorption curve usually requires several hours, certain difficulties were encountered in the determination. These were: (a) the sample solutions deteriorated on standing and (b) the sample solutions are affected by heat.

To compensate for these problems it was necessary to prepare various samples of the same aliquot during the complete test. Usually, a sample solution was stable for 15 min. after completion of the centrifuging. In past practice the sample was measured immediately at a selected frequency after centrifuging. Then various per cent transmissions at other frequencies were measured with the per cent transmission at the initial frequency being checked after several readings. When the reading for the initial frequency changed appreciably, the sample was discarded and another sample was prepared of the same concentration.

The other difficulty was partly compensated by using the spectrophotometer over only relatively short periods. When preparing another sample, the lamp switch was turned off to cool down the machine, but the selector switch was left on the check position. When ready for measuring another sample, the lamp switch was turned on several minutes before actual measurements.

The samples selected were in the medium concentration range. Read-

ings were taken at 5- and 10-mμ. intervals, depending upon the frequency being measured. Although optical densities can be easily measured and plotted on arithmetic paper, per cent transmission readings were made so as to give a better conception of the results. As even samples selected from the same concentration will give somewhat different readings due to experimental errors, it was necessary to take these differences into account.

From a plot of per cent transmission *versus* frequency, great absorption was indicated at 545 and 655 mμ. With these two frequencies, and also at 525 mμ. to compare with selected frequency for the Fisher electrophotometer, per cent transmission was measured for various concentrations of naphthalene.

Results

The greatest success was attained with the Fisher electrophotometer. This device was supplied with three filters, but as no calibration was supplied with the filters (with the exception of the approximate frequency, but no mention of the band width) it was necessary to calibrate them. From this calibration and from the spectrophotometric absorption curve, the filter that approximated the correct frequency was the 525-mμ. filter. This filter actually had the maximum absorption at 527 mμ., but covered a band from 513 to 545 mμ.

Following centrifuging, the sample to be measured was placed in a clean dry cell and placed in the electrophotometer. Chloroform was used in the blank cell. Readings were measured by first checking the 100 per cent transmission with the blank, then getting the per cent transmission of the sample, and then rechecking the 100 per cent transmission of the blank. If the 100 per cent transmission did not change, the reading of the sample was assumed correct.

Aliquots to cover the range from 0 to 234 p.p.m. were measured. A summary of the results is given in Table I. These data were plotted on semi-log paper using the per cent transmission as the ordinate and the concentration of naphthalene as the abscissa.

TABLE I.—Summary of Naphthalene Analysis by Electrophotometer

Sample No.	Naphthalene (p.p.m.)[1]	Average Reading	Av. Indiv. Dev. from True Values (%)	Av. Dev. from Col. 2 (p.p.m.)
1–7	0	93.4	—	—
8–12	4.7	90.3	22.0	1.0
13–18	9.4	87.5	18.0	1.4
19	18.7	83.0	0.0	0
20–29	23.4	80.8	9.8	2.1
30–39	46.8	69.4	8.8	4.4
40–49	70.2	60.3	5.4	3.8
50–59	93.6	49.4	5.9	5.5
60–69	117.0	44.3	5.5	6.7
70–79	140.0	37.3	6.1	8.6
80–89	164.0	31.0	3.6	5.9
90–99	187.0	27.4	3.8	7.3
100–110	211.0	23.2	3.9	9.5
111–120	234.0	20.1	3.8	8.8

[1] In 100-ml. aliquots.

[2] Average deviations of samples 8–120 = ±7.5 per cent; average deviations of samples 20–120 = ±5.6 per cent.

The results with the Fisher electrophotometer were very consistent, especially in the range of 0.2 to 200 p.p.m. These results indicate that the deviation was only ± 5.6 per cent in the 20- to 234-p.p.m. range, and ± 7.5 per cent over the entire range of 0 to 234 p.p.m. In quantities less than 0.2 p.p.m., however, the accuracy decreases to a large percentage so that below the limits of 0.2 p.p.m. the results cannot be used.

These results can be expressed as an equation, whose derivation is as follows.

The general equation of a straight line on a semi-log plot is

$$y = n\,10^{mx} \quad \ldots\ldots\ldots\ldots (1a)$$

$$\log y = \log n + m\,x \log 10 \quad \ldots (1b)$$

$$x = \frac{\log y - \log n}{m} \quad \ldots\ldots (1c)$$

in which y = per cent transmission, x = quantity of naphthalene, n = intercept on y-axis, m = slope of the line, and V = volume of original solution. Inasmuch as the slope, m, was -0.0134 and the intercept on the y-axis, n, was 93.5,

$$x = \frac{\log y - \log 93.5}{m} \quad \ldots\ldots\ldots (2a)$$

$$x = \frac{\log y - 1.9708}{-0.0134} \quad \ldots\ldots\ldots (2b)$$

$$x = (-75.3)(\log y - 1.9708) \quad \ldots (2c)$$

But x in this calculation is actually 4.68×10^{-3} mg. of naphthalene (concentration of naphthalene). To put into p.p.m., the volume also must be considered.

$$x = \frac{(-75.3)(\log y - 1.9708)(4.68)}{V} \quad \ldots (3a)$$

Or, simplifying,

$$x \text{ (in p.p.m.)} = \frac{352(1.971 - \log y)}{V} \quad \ldots (3b)$$

Discussion

Straight lines dissimilar only in slopes were obtained by using the spectrophotometric frequencies of 525 and 545 mμ. and the electrophotometric 525-mμ. filter. Of the three, the maximum absorption was obtained using the 525-mμ. filter of the electrophotometer. This was probably due to the wide band of frequencies that this filter covers. The results using the 655-mμ. frequency of the spectrophotometer, resulting in a curved line, showed the highest absorption of any of the frequencies employed.

In some instances the color of the final chloroform-naphthalene solution varied from a blue to a bluish-purple or even purple solution. This phenomenon may be explained as being due to possible interferences as water, deteriorated $AlCl_3$, or possibly foreign substances in the original solution. This change in color plays havoc with the 655-mμ. frequency of the spectrophotometer, causing large differences in the per cent transmission readings for the same concentrations of naphthalene. In the use of the 525- and 545-mμ. frequencies small changes of from 1 to 3 per cent are registered, but with the Fisher electrophotometer the change in color from blue to even purple appears to indicate no measurable change in measurement. For this reason, a filter with a wide band is preferred.

Since a straight line did occur at 545 mμ. on the spectrophotometer and on the 525-mμ. filter of the electrophotometer, one of these two frequencies should be used in preparing the standard chart. For approximate results the developed equation can be applied for any frequency from 520 to 545 mμ. with an accuracy of about 10 per cent.

The care required in the actual determination is small but very necessary. Water interferes if found in the final chloroform solution, but it is easily removed. Also essential is the ordinary procedure of using dry and clean glassware, accurate and careful pipetting, and a fair laboratory technique.

A mechanical shaker will prove valuable. The reaction, as stated previously, takes at least 5 min. of vigorous shaking. If a mechanical shaker is not available and cannot be constructed, a standard chart can be constructed by shaking the separatory funnel for a definite time interval. The correct amount of shaking should be determined in a manner similar to that used in the time of contact experiment conducted in this analysis.

Individual interferences may cause trouble when this method of analysis is applied to different trade wastes. There are very few general analyses that are exempt from all interferences and this method is probably not an exception. The general interferences

found in coke oven wastes were eliminated, so that the method is applicable to the analysis of naphthalene in this industry. With the elimination of any interference that may appear in any other industry, this method easily can be applied to the determination of small quantities of naphthalene.

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WASTE AND POLLUTION CONTROL COURSES

Among the courses in industrial waste and water pollution control being offered by the U. S. Public Health Service Environmental Health Center, Cincinnati, Ohio, during the period ending June 30, 1953, are the following:

October 13–24, 1952—Examination of Polluted Waters and Industrial Wastes.

December 1–12, 1952—Advanced Training for Sanitary Chemists in Water Pollution Investigations.

January 12–16, 1953—Advanced Training in Bacteriological Examination of Water.

February 18–20, 1953—Short Course in Phenol Determination.

March 2–13, 1953—Advanced Training for Sanitary Engineers in Water Pollution Abatement Programs.

May 4–8, 1953—Aquatic Biology Training.

May 20–22, 1953—Short Course in the Analysis of Metals in Industrial Wastes.

The courses are offered for professional personnel from state and local health departments, water pollution control agencies, the U. S. Public Health Service, and other governmental units, as well as representatives from industry who are cooperating with these agencies in environmental sanitation.

Information concerning the courses may be obtained from the Officer in Charge, Environmental Health Center, U.S.P.H.S., Cincinnati, Ohio.

LABORATORY ORGANIZATION AND TECHNIQUES FOR LARGE-SCALE SEWAGE AND INDUSTRIAL WASTE TESTING*

By N. J. Krotinger

Bureau of Standards, Dept. of Public Works, Los Angeles, Calif.

Provisions of the Los Angeles City Charter place upon a Board of Public Works responsibility for disposing of all wastes that would affect the health and comfort of the municipality's citizens. As this board is an executive body only, it maintains under its jurisdiction several bureaus, to which are delegated the tasks of designing, constructing, and operating waste disposal facilities. Design is assigned to the Bureau of Engineering, construction to the Bureau of Inspection, and operation to the Bureau of Sanitation. The Bureau of Standards performs the testing work for all Department bureaus.

Laboratory Services in Disposal of Liquid Wastes

A separate division of the organization for disposal of liquid wastes is set up to control wastes produced by industry. A city ordinance requires that water that can be safely dispatched through storm sewers and open water channels may not be discharged into sanitary sewers. This regulation is necessary because of the overload on sanitary sewers. Enforcing it necessitates the taking and analyzing of many samples from storm drains and watercourses.

Because the Los Angeles outfall sewer is exceptionally long, extending from the upper end of San Fernando Valley to the Hyperion sewage treatment plant on Santa Monica Bay, a distance of 52 mi., and because the temperature of the sewage is ideal for bacterial and slime growth, many operational problems arise that are not common to sanitary sewers in general. Corrosion of the conduit is severe and disagreeable odors escape to annoy the populace and harass the maintenance personnel. Services of the laboratory are utilized in solving these problems.

Laboratory Testing of Industrial Wastes

Section 64.30 of the Los Angeles Municipal Code specifies that liquid wastes discharged into sanitary sewers or storm drains shall have a pH between 5.5 and 9.0 and shall contain not more than 600 p.p.m. of oil or grease, or more than 1,000 p.p.m. of suspended solids. The California Water Pollution Control Board limits the water pollutant constituents of discharges into drainage channels.

To insure compliance with regulations, analyses are made monthly of water in the Los Angeles River and in storm drains that discharge directly into Los Angeles Harbor. Discovery of excessive contamination is followed by extensive upstream sampling to locate its source. Eighteen Industrial Waste Inspectors are employed in the field, checking industries and sampling wastes.

Samples received at the laboratory are registered, identified with register numbers, and assigned to members of the staff for analysis. Tests are usually made in accordance with "Standard Methods" (1). It is sometimes

* Presented at 24th Annual Meeting, California Sewage Works Assn.; Santa Cruz, Calif.; April 23–26, 1952.

necessary, however, to adapt other methods to the analysis at hand.

Some of the recently developed electronic equipment is being utilized to speed up testing and to increase the field of analysis and the accuracy of findings. Use of a Perkin-Elmer flame photometer has reduced the time consumed in determining sodium and potassium to a small fraction of that previously required. Time required for determining calcium and magnesium is being shortened by use of the versenate method (2) (3). Installation of a Beckman infrared and ultraviolet spectrophotometer has increased the range of analysis, particularly in determining small quantities of organic compounds. The infrared spectrophotometer makes possible the identification and measurement of small quantities of organic wastes not determinable by ordinary laboratory methods. Wastes discharged by industry are abundant in such material.

In the seasonal surveys of the Los Angeles River the load of chemical pollutants, sanitary pollutants, amounts of grease, oxygen depletion of the water, and the condition of the river banks are noted. The pH, temperature of the air and water, and dissolved oxygen are determined in the field; also biochemical oxygen demand (B.O.D.) and coliform organism tests are set in the field. Chlorides, grease, and alkalinity are determined in the laboratory as are also total, fixed, and volatile suspended solids and total dissolved solids.

Testing in Trunk Sewers

Trunk sewers, where they enter the main outfall, are sampled monthly. Included in the schedule are samples from the detritors of the Hyperion sewage treatment plant and from the Venice pumping plant. Analysis includes tests in the field and in the laboratory. Tests conducted in the field are: pH, temperature of air and sewage, total sulfides in sewage, hydrogen sulfide in the air, velocity of air in the sewer line, type and intensity of odors, and the condition of a concrete ball suspended from a rung of the manhole ladder. A 5-day B.O.D. sample is set in the field. In the laboratory, tests are made for grease, for total, fixed, and volatile suspended solids, and for total dissolved solids. A chemist and one assistant are used in these monthly surveys; the time required is two days in the field and one in the laboratory. All data are recorded on prepared forms.

Data for use in design of ventilated sewers are compiled in these monthly surveys. The direction (in or out) and velocity of air flow of the sewer is recorded. Air velocity is measured by an anemometer set in the center of a wood disk that is placed over the manholes. Hydrogen sulfide and odor intensity measurements are not made where air flow is into the sewer.

Sewer odors are identified as fecal, urinous, solvent, soapy, etc., and their intensity is recorded as strong, moderate, or slight. To concentrate the odor, the manhole is covered for a few minutes before testing. Threshold concentration—that is, percentage of sewer air mixed with fresh air, in which sewer odor is just perceptible—is measured by a device developed at the laboratory. It is essentially a hand-operated blower with inlet valves that can be set to mix different percentages of sewer air and fresh air. Calibration of this instrument is accomplished with anemometers set in both the fresh air and sewer air inlets, the blower being operated at constant speed.

The concrete balls mentioned are used in determining the rate of attack of sewer gas on the concrete walls of the sewer. These balls are pear-shaped, made of portland cement concrete, and used in evaluating protective coatings as well as measuring the rate of corrosion. The pear-shaped specimen was developed to eliminate complaints of unfair testing made by protective coat-

TABLE I.—Analytical Methods Used

Item	Method[1]
Solids	A. P. H. A.
Grease	Wet extraction
pH	Electrometric
Alkalinity	A. P. H. A.
Conductivity	Electrometric
Phenol	A. P. H. A. (Gibbs)
Boron	A. P. H. A.
Fluoride	A. P. H. A.
Sodium	Flame photometer
Potassium	Flame photometer
Calcium	Versenate titration
Total hardness	Versenate titration
Magnesium	Versenate titration
Chromium	A. P. H. A.
Sulfate	A. P. H. A.
Chloride	A. P. H. A.
Ammonia nitrogen	A. P. H. A.
Nitrate nitrogen	A. P. H. A.
Silica	A. P. H. A.
Iron	A. P. H. A.
Aluminum	A. P. H. A.
Sulfide	A. P. H. A.

[1] A. P. H. A. refers to reference (1).

ing representatives. Plaques 1 in. by 8 in. by 8 in., previously used, had sharp edges and corners, and failure of protective coatings usually started at the sharp corners. Periodic examinations of these balls give data from which the life of the sewer can be computed. Their greatest value, however, is in locating points of high corrosion where early repairs may be necessary.

Publicity has been given to the idea of supplementing the water supply of Southern California by reclaiming the effluent from Los Angeles sewage treatment plants and pumping it into the underground water-bearing strata. Studies in connection with this are being made by the Bureau of Engineering and the laboratory is assisting with analyses of sewage in all trunk sewers. This testing program has been under way for 21 weeks, the schedule providing for 24-hr. composite samples taken every eighth day. Samples are weighted composites based on the flow. A 1-qt. sample of the composite is preserved with copper sulfate and a 2-qt. sample is preserved with chloroform. Samples are stored under refrigeration until tested and, except on

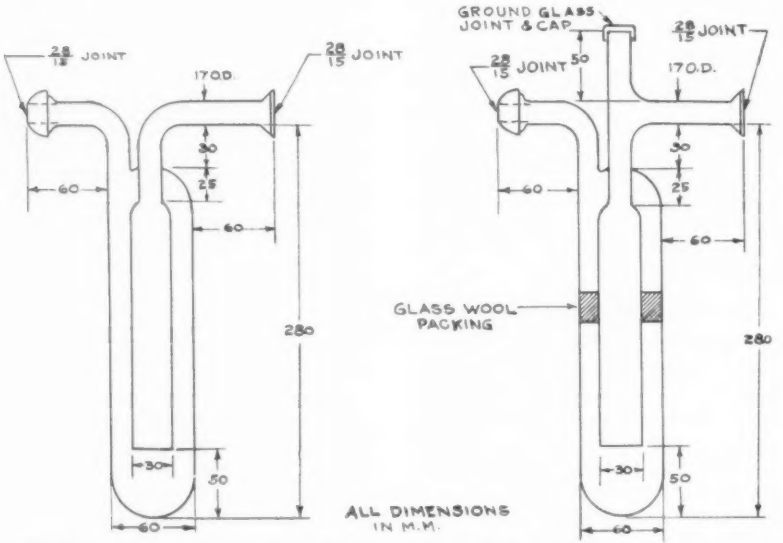

FIGURE 1.—Freeze-out trap (left) and modified Shepherd trap (right) for fractionating odor-producing constituents from sewer gas.

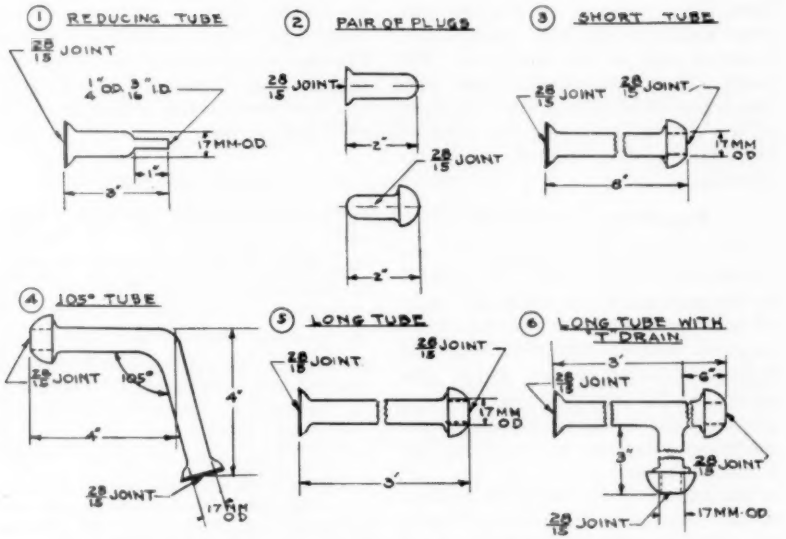

FIGURE 2.—Appurtenant plugs and tubes for freeze-out traps.

week-ends, analysis is started immediately after samples are received. Samples received on week-ends are transferred to metal containers and frozen in a deep-freeze unit. Biological growth is stopped by this treatment. The sample preserved with copper sulfate is used only for determining phenols; all other tests (Table I) are made on the sample preserved with chloroform.

In sewage of the North Outfall sewer a great reduction in sulfides was noted after ventilated manholes were installed. This discovery, followed by tests and inspections, resulted in the conclusion that ventilation will reduce corrosion and obnoxious odors and retard development of septicity. This observation, supplemented by many complaints concerning odors, has stimulated interest in ventilating major sewers. Removal of odor from the discharged air is necessary if mechanical ventilation is to be installed.

Members of the laboratory staff are studying conditions that produce odoriferous sewers and methods of preventing odor formation. A chemical engineer, employed under contract, is investigating means of destroying obnoxious odors.

A new approach to the odor problem is being tried. Odor-producing constituents are being frozen out of the sewer gas and the various fractions subsequently analyzed. The sewer air is passed through five freeze-out traps (Figure 1). Cooling media used are dry ice and alcohol, liquid nitrogen, or liquid oxygen. The first two traps in the freezing-out line are filled with glass Raschig rings, otherwise being identical with the second pair. The fifth trap is of the Shepherd type (Figure 1), without stopcocks (4). The purpose of the Raschig rings is to increase the condensation surface. The Shepherd trap serves as a "safety man" to stop any odors that pass through the first four traps. Appurtenant plugs and tubes for the traps are shown in Figure 2.

Preliminary tests were made on the San Fernando Valley line. Materials of two distinct odors were condensed

from the sewer air; in the first two traps a solvent odor was obtained, and a stench odor in the last three. For years a heavy stench odor had been characteristic of this sewer. Analysis of the solvent odor with the infrared spectrophotometer proved it to be pyridine.

Reporting Test Results

Wherever possible, reports are made on standard forms. They are drafted by the operator performing the analysis and checked by an associate engineer, a testing engineer, and the Bureau director before being dispatched to the bureau concerned. Samples on which action is pending are reported by telephone and confirmed by a written report.

The Bureau of Standards of the City of Los Angeles, in its function of serving other bureaus of the Department of Public Works, analyzes sewage, sewer gas, and industrial wastes. Thousands of analyses and tests are performed each year and special methods and organization are required to meet this volume.

Acknowledgment

The odor intensity measuring apparatus was designed by C. W. Beardsley. T. C. Wilson worked out the plan of industrial waste testing.

References

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3. Walker, A. O., and Robertson, R. S., *Power Generation*, **54**, 81 (1950).
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PENNSYLVANIA TO HOLD CLEAN STREAMS CONFERENCE

"Water—Our Greatest Asset" will be the theme of a statewide Clean Streams Conference to be held in Harrisburg, Pa., on November 12, 1952, under the sponsorship of the Pennsylvania State Chamber of Commerce and 11 cooperating state, municipal, sportsmen's, and technical groups, including the Pennsylvania Sewage and Industrial Wastes Association.

The conference, first cooperative undertaking of its kind in Pennsylvania, is open to all persons interested in the state's water resources and what is being accomplished under the Commonwealth's clean streams program to correct the misuse of public waters. The program, featuring non-technical talks, movies, and an open discussion period, is designed to be of interest to sportsmen, industry, municipalities, and civic groups.

The conference will be held in the Penn-Harris Hotel, Harrisburg, Pa., beginning at 10 AM on November 12, 1952. The only charge for attendance will be for the luncheon. Reservations are being handled by the Pennsylvania State Chamber of Commerce, State Chamber Building, Harrisburg, Pa.

SUCCESSFUL TREATMENT OF DAIRY WASTE BY AERATION *

By G. E. Hauer

Chief Engineer, American Well Works, Aurora, Ill.

The treatment of dairy waste has been, and continues to be, a serious problem. The voluminous published reports of research and operation on this particular phase of pollution abatement will testify to the seriousness of the situation. Undoubtedly, the regulatory agencies are in the best position to review and render judgment on the progress, or lack of progress, that has been made; but certainly the high degree of treatment which is economically possible by the aeration process should encourage more universal treatment of the troublesome dairy wastes.

Although it should never be considered that the present method of treatment is the final answer and that research and development should be dispensed with, it is believed that a satisfactory aeration process has proven itself and more specific conclusions can be made at present than have been made in the past. Bloodgood (7) a few years ago concluded that milk wastes can be treated in suitable treatment plants designed with adequate capacity. Also, that decreased cost of construction and operation of milk waste treatment plants will result from further study of economical construction and increased purification per unit of plant volume. A definition of "adequate" and "suitable" must be given, even at the risk of controversy and misunderstanding, if a forward step is to be taken to free the streams from the highly obnoxious dairy wastes.

* Presented at 1952 Annual Meeting, New Jersey Sewage and Industrial Wastes Assn.; Atlantic City, N. J.; March 12–14, 1952.

Status of Problem

In defining a successful treatment, it must be considered and agreed with Trebler and Harding (2) that:

"One thing is certain: It is worse than useless to build expensive waste disposal units if no economical way can be found for keeping them in good operating condition, perferably the year around. Fully automatic, absolutely foolproof disposal units have not as yet been made to operate without any attention for days or months on end. Until such units are manufactured, the greatest progress in elimination of pollution due to dairy waste will be made by (a) improved waste saving devices and improved equipment and waste preventing devices within the milk plants, (b) new or improved methods of by-product utilization, and (c) dairy waste flow equalization and admission of dairy waste to city disposal plants."

It is believed that the results produced in treating dairy wastes by aeration fulfill the requisite for an economical plant which can produce a high degree of treatment with a minimum of maintenance. The need for waste saving and waste preventing devices will always be apparent; and the economy provided with such an approach is a principal factor in the treatment program. As an illustration, Eldridge (10) has reported a waste prevention program at Belle Center, Ohio, which resulted in a reduction of from 60 to 70 per cent of the B.O.D. load to be treated.

By-product utilization undoubtedly will continue to be a variable factor depending on market and other conditions. Likewise, the proper admission

of dairy wastes to municipal systems will continue to be determined by the economics of the situation, involving location and degree of treatment required and/or available.

Theory of the Aeration Treatment

The aeration process for milk waste treatment adapts itself as a successful treatment because it primarily accomplishes a high percentage removal of B.O.D. with a minimum of plant installation and maintenance. The raw waste flows directly to the aeration tank, with the overflow going to a settling tank. Sludge is recirculated to the raw waste, with only an occasional discharge of the sludge to a point of final disposal, such as a sand drying bed. The design factors are discussed subsequently, but it is readily apparent from the simplicity of the process that economical structures can be made which will adapt themselves to the particular milk processing plant. Normal maintenance of pumps and air compressors can be expected; but the continued use of skilled operators has been found unnecessary.

The process of aerating dairy wastes with or without return sludge has been variously termed from activated sludge to aerobic digestion. In this paper the subject is considered only as a process of aeration and the results obtained are reviewed with no attempt to accurately define the biological aspects. However, the recent fundamental research of Hoover, *et al.* (4) (5) (6), is worthy of mention and consideration when explaining the aeration of dairy wastes. It has been found by continuous aeration studies in the laboratory (6) that "There are . . . major points which deserve consideration by sanitary engineers. . . . the extremely high rate of assimilation of dairy wastes by microorganisms increases the oxygen demand of the flora greatly and, if this demand is met, dairy wastes and related strong organic wastes might be satisfactorily treated in conventional systems. If aerobic conditions are maintained, by-products of oxidation are negligible, and acids do not accumulate." The practical significance of these statements is self-evident.

Other interesting results (6) from the laboratory show that the soluble organic matter of simulated dairy waste was removed completely by oxidation or by assimilation into cell tissue, which could then be removed as sludge. Studies have shown that approximately 50 per cent of the milk solids are converted into cell tissue or sludge, with the remaining 50 per cent oxidized to carbon dioxide and water. Supplementing this was the finding (6) that "the lactose content of the effluent was zero throughout the experiments—the protein content of the effluent was essentially equivalent to the total content of nitrogenous materials (protein plus proteose plus nonprotein nitrogen compounds) in the influent." The period of aeration for these experiments varied from 9.5 to 20 hr.

Before setting forth the practice and results of aerating dairy wastes, some brief comment should undoubtedly be made as to the status of the biological trickling filter. Recommendations (2) have been made for using 1 cu. yd. of filter media per pound of B.O.D. per day with anticipated results of 60 p.p.m. B.O.D. in the effluent when the raw waste contains approximately 1,000 p.p.m. B.O.D. Other recommendations (1) have been for only one-third of this loading to reduce the pollutional strength of the wastes 80 per cent or more. In many instances an 80 per cent removal of B.O.D. is not satisfactory. Perhaps the position of the trickling filter in the dairy waste treatment program can best be summarized by the recent statement of the Pennsylvania Association of Milk Dealers, Inc. (7):

"In spite of the effort to simplify and improve trickle filter construction, the feeling in the dairy industry is that construction costs are too high in proportion to the cost of the milk plants themselves and that

some cheaper treatment method must be found if pollution elimination is going to make rapid progress. Also, most small trickle filter plants are difficult to keep in operation in the wintertime and occasionally odor complaints arise. In addition, the argument is made that since the flush season for milk production is relatively short, it should be most economical to build highly flexible waste treatment plants with a minimum of construction cost even if this might mean relatively higher power cost for short periods of operation during the flush months. As a consequence, several new installations of the return or activated sludge type have recently been made in an effort to see if this would not give a more economical answer to the dairy waste disposal problem."

Practice and Results

Treatment by aeration has been installed in a few dairy products plants for several years. In fact, operating results have been recorded for a period sufficiently long that the practical conclusions can now be removed from the experimental classification.

One of the earlier aeration plants was installed at the Maplehurst Dairy, Springdale, Conn., under the supervision of the National Dairies Research Laboratories. The plant was designed for a maximum flow of 16,000 g.p.d. and a flow period of 14 hr. The anticipated B.O.D. was 110 lb. per day. The raw waste is added directly to one aeration tank consisting of a steel tank 11 ft. in diameter and 20 ft. high. Utilizing a water depth of 19 ft., the volume for aeration is 14,250 gal. This tank was equipped with 3 jet aerators having a total air capacity of 36 c.f.m.

In October, 1948, the B.O.D. reduction averaged from 94 to 98 per cent with an average raw B.O.D. of 1,100 p.p.m. and a range of B.O.D. in the effluent from 26 to 50 p.p.m. Later series of tests in the same year show an average B.O.D. reduction of 96.1 per cent with a total raw B.O.D. amounting to 73 lb. per day and the B.O.D. in the effluent amounting to 2.9 lb. per day. A still later series gave an average B.O.D. reduction of 99.1 per cent. The average oxygen absorption during these tests was 8.0 to 8.6 per cent.

The following year, when handling between 7,000 and 10,000 g.p.d. of waste and a B.O.D. loading of from 56 to 81 lb. per day, the average reduction in B.O.D. varied from 70 to 96 per cent. In January, 1949, the B.O.D. in the effluent varied from 9 to 124 p.p.m.

These results are typical of those produced by simple and economical aeration plants, which in addition to the Springdale, Conn., installation, are located at Stockton, Huntley, and Chemung, Ill.; Tonganoxie, Kan.; and Owenton, Ky.

The Huntley and Chemung plants are owned by the Dean Milk Company. Due to the unusually active interest of the owner, the engineers, and the Illinois State Department of Health (8) (9), there are considerable data available on the treatment at these locations.

The Huntley plant (Figure 1) treats the waste from a 200,000-lb. milk bottling plant. The raw waste flows through a trapped manhole to remove the paraffin resulting from the bottling machine operation and then goes to the treatment plant site, where the flow is measured by means of a weir box. A fine-mesh screen removes residual paraffin and also other debris resulting from washing operations. From the weir box, the flow is into a collecting sump adjacent to the aeration tank. The recirculating pump takes its suction from this collecting sump and supplies the waste and mixed liquor to the 6 jet aerators located within the aeration tank. In the collecting sump, there is also a float valve, which automatically returns mixed liquor directly from the aeration tank into the sump to provide constant water level. Thus, during periods of no waste discharge from the milk plant, the float valve allows the larger quantity of aeration tank con-

tents to be returned and recirculated through the jets. The pump, therefore, serves the dual purpose of raising the raw waste into the aeration tank and supplying the jet liquor, which insures proper dispersion of the air with high oxygen absorption.

The aeration tank is 20 ft. 6 in. long by 11 ft. wide by approximately 8 ft. deep. Two headers of 3 jets each are placed transverse to the flow. The settling tank is adjacent to the aeration tank, utilizing a common-wall construction. Three baffled ports allow the flow of mixed liquor into the tank and an overflow weir on the opposite side removes the effluent. The settling tank is 8 ft. by 11 ft. with a hopper bottom to provide an effective capacity of 2,100 gal. The sludge is removed and returned to the aeration tank by means of an air lift taking air from the same compressor which supplies the jets. An additional connection in the air lift discharge allows sludge to be wasted at the discretion of the operator.

Although practically continuous operating results are available, reference is made to the data (8) obtained during a study by the Illinois Sanitary Water Board during 1949 and 1950. These results were as follows: sampling period, 8.5 to 10 hr.; average flow during sampling period, 21 g.p.m. (11,200 gal. total); total flow during 24-hr. period, 15,200 gal.; aeration tank detention, sampling period, 10.7 hr.; aeration tank detention, 24-hr. period, 21 hr.; settling tank detention, sampling period, 1.67 hr.; settling tank detention, 24-hr. period, 3.3 hr.; B.O.D. reductions, 66.7 to 97.3 per cent; B.O.D., raw waste, 936 p.p.m.; B.O.D. final effluent, 172 p.p.m.; air supplied, 1,045 cu. ft. per pound of B.O.D., or 0.73 c.f.m. per pound of B.O.D.

It was determined during the studies that the lower B.O.D. reductions were due to the carryover of light and fluffy floc particles. If this floc were removed, a higher percentage B.O.D. reduction would have been recorded.

Another fact disclosed by these studies was that not every type of air diffusion will operate satisfactorily. With poor air diffusion the amount of air introduced means little. In the design of such a plant, the method of air diffusion becomes a critical factor. The original air diffusion equipment was

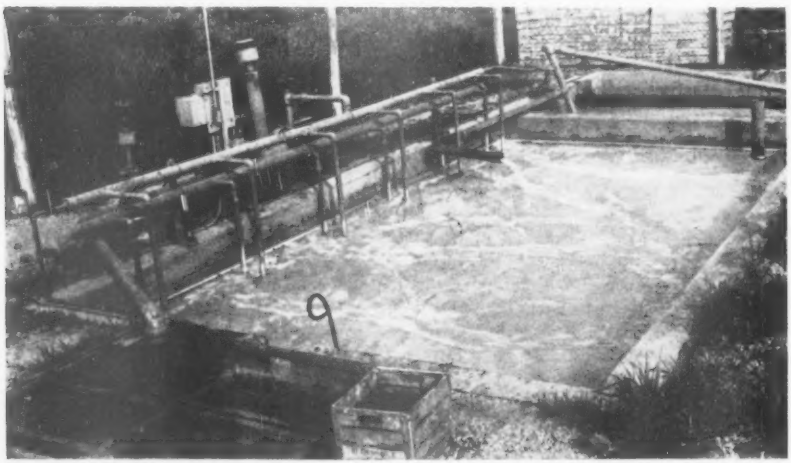

FIGURE 1.—Aeration plant for milk waste treatment, Dean Milk Co., Huntley, Ill.

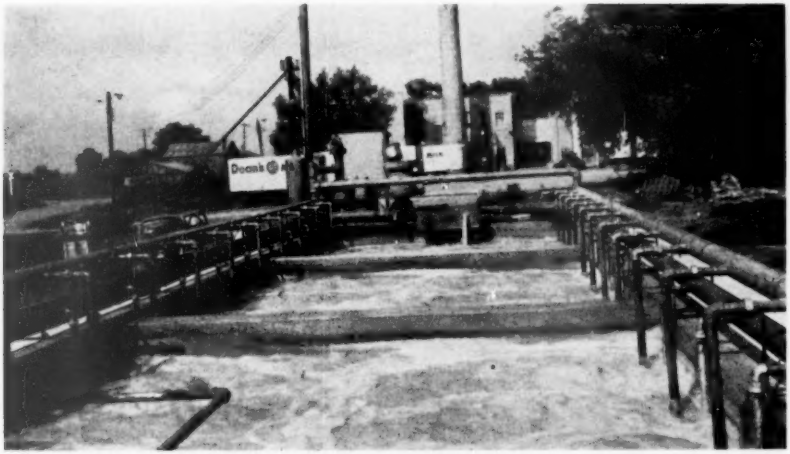

FIGURE 2.—Influent end of milk waste aeration plant, Dean Milk Co., Chemung, Ill.

replaced during this series of tests with jets and it was found that all upsets due to decreased aeration efficiency were eliminated.

Other conclusions are that approximately 1,100 cu. ft. of air should be provided per pound of B.O.D. in the raw waste per day, with an aeration tank having a capacity of nearly one day's flow and using jet-type aerators. Inasmuch as careful attention must be given to the removal of the activated floc in the final settling tank, it is imperative that good baffling and settling characteristics be obtained. Regular facilities for disposing of sludge are not needed. Most of the solids are "burned up" in the treatment process. If a provision is made for measuring flow and collecting weighted samples, the dairy will be provided with a record of plant losses.

The Dean Milk Company's waste treatment plant at Chemung, Ill. (Figures 2 and 3) was placed in operation approximately two years ago. This plant is considerably larger than the Huntley installation and has an aeration tank 12 ft. by 36 ft. by 10 ft. for a design flow of 55,000 g.p.d. The original installation utilized 22 jets. However, operation indicated that less air could be used, so 11 jets were removed from operation. Operation at both the Chemung and Huntley plants has continued to improve, due to the close supervision of the consulting engineers, and the current operation reported at these plants is as follows:

	Plant	
	Huntley	Chemung
Raw waste B.O.D. (p.p.m.)	950	1,150
Total volume (g.p.d.)	15,000	53,000
B.O.D., total (lb./day)	119	508
Air volume (c.f.m.)	70	264
Air supplied (cu. ft./lb. B.O.D./day)	842	759
B.O.D. reduction	85 to 97	75 to 85
D.O. in aeration tank (p.p.m.)	1.0 to 6.0	1.0 to 6.0

In evaluating these data, it must be kept in mind that the Huntley results are based on prolonged permanent plant operations, whereas the Chemung results are based on a relatively short operating period during which certain adjustments in operating procedures were, and still are, being made to coordinate all the factors involved.

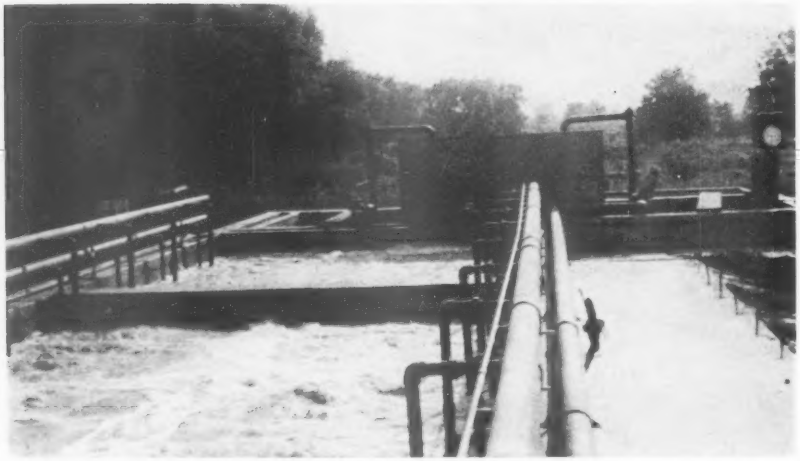

FIGURE 3.—Effluent end of milk waste aeration plant, Dean Milk Co., Chemung, Ill.

In regard to the Chemung plant, consistent plant operation will likely tend towards the use of less air to effect a better balance between D.O. in the aeration tank and other factors. Improvement in settleability characteristics of the sludge will result in a marked increase in over-all plant B.O.D. reduction and it is anticipated that plant operation will eventually involve procedures tending toward that result.

ample D.O. in the aeration tank, irrespective of normal shock loadings incidental to fluid milk plant operations involving bottling of milk and/or manufacture of cottage cheese.

Dairy waste has been treated successfully by aeration at installations other than those already mentioned. A recent report (10) for two plants located in Ohio has been made available; for purposes of comparison, the results are tabulated as follows:

	Schell Dairy, Germantown, Ohio	Blossom Hill, Dayton, Ohio	Dean Milk Co., Chemung, Ill.	Dean Milk Co., Huntley, Ill.
24-hr. flow (g.p.d.)	4,400	7,200	53,000	15,000
Duration of flow (hr./day)	8	7	10[1]	10[1]
Aeration time, sampling period (hr.)	—	—	—	10.7
Basis 24-hr. flow (hr.)	39.4	41.2	14.7	21
Settling time, sampling period (hr.)	—	—	—	1.67
Basis 24-hr. flow (hr.)	2.53	3.22	—	3.3
Av. rate of flow (g.p.m.)	10.5	15.0	88[1]	21.0
B.O.D., raw (p.p.m.)	567	926	1,150	950
B.O.D. removal (%)	96.5	96.5	75 to 85	85 to 97
Air supplied (c.f.m./lb. B.O.D.)	4.08	1.8	0.52	0.59

[1] Approximately.

It can be said that the two plants have an excess of air for the process and have always been able to maintain

It will be noted that the current operations at Chemung and Huntley are utilizing 0.52 and 0.59 c.f.m. of air

per pound of B.O.D. whereas the earlier studies at Huntley reported 0.73 c.f.m. per pound B.O.D. Inasmuch as recent operation is reportedly superior, it is obvious that approximately 0.6 c.f.m. per pound B.O.D. can be used, providing the air is properly dispersed in the aeration tank. In addition, the method of aeration must not only provide proper tank turnover, but must also provide a high percentage of oxygen absorption. Operation at the one plant in Ohio consumed approximately 800 per cent more air when using plastic wound diffuser tubes.

Summary

The treatment of dairy waste by aeration has been successful over a period of some years. On the basis of results reported, it may be concluded that B.O.D. reductions approaching 97 per cent can be obtained with the use of as low as 0.6 c.f.m. of air per pound of B.O.D. As a general design basis, 1.0 c.f.m. per pound B.O.D. might be used. The aeration tank should have a detention period of approximately 10 hr. based on the flow during the normal 10-hr. operating period, or approximately 21 hr. detention based on a 24-hr. flow period. The final settling tank should have a detention period slightly longer than those presently designed, so that a minimum of 2 hr. will be obtained during peak flows. The weir rate should be sufficiently low to prevent carryover of light floc particles. The sludge should be continuously returned to the aeration tank with the raw waste, with only occasional wasting of excess sludge. The air should be introduced into the aeration tank by a mechanical means which will not clog and which will provide high oxygen absorption. The recirculation of mixed liquor through the jet-type aerator has proved to be a definite advantage and is possibly the explanation for the satisfactory treatment being obtained with low air consumption.

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WHITE WATER TREATMENT *

II. Effect of Sulfides on Digestion

By Willem Rudolfs and Herman R. Amberg

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Suspended solids can be effectively removed from white water to about 90 per cent by chemical coagulation and settling, regardless of the coagulant employed (5), with reductions of B.O.D. ranging between 20 and 40 per cent. Studies on certain factors affecting anaerobic digestion of white water concentrate showed that the loadings and efficiencies attainable at the optimum conditions were very low.

Alum is used in the paper making, and recirculation of the liquid waste results in a subsequent increase in sulfate concentration, which may range from 1,000 to 2,000 p.p.m. Although a considerable amount of experimental work has been reported regarding the effect of sulfates upon the digestion of organic materials (2)(3)(6)(7), only indirect evidence is available to indicate that sulfides may be toxic to the digestion process.

In the course of fundamental studies regarding the intermediate and end products produced during digestion, it appeared that sulfides tend to accumulate under certain conditions in sufficient quantity to exert a toxic or retarding effect on gas formation. A gradual increase of soluble sulfides to as high as 200 p.p.m. seemed to be related to the rate of gas production.

Materials and Methods

Samples of white water obtained from a paperboard mill were concentrated by evaporation and analyzed, with the following results:

Total solids (p.p.m.)	7,800
Volatile solids (p.p.m.)	4,290
Dissolved solids (p.p.m.)	5,800
Suspended solids (p.p.m.)	2,000
Susp. volatile solids (p.p.m).	1,090
B.O.D., 5-day, 20° C. (p.p.m.)	2,120
Total N (p.p.m.)	31
Sulfate (p.p.m.)	1,500

Ripe sewage sludge was mixed with white water concentrate in a ratio of 2:1 on the basis of volatile matter present. Because the feed was deficient in N and possibly P, diammonium acid phosphate was added to insure a B.O.D.-nitrogen ratio of 20. Soluble sulfide was added to the feed in the form of $Na_2S \cdot 9H_2O$ and the resultant alkaline solution neutralized to pH 7.0 with concentrated HCl. The experiments were conducted at 35° C., the gas was collected, and analyses were made in accordance with "Standard Methods" (8).

Relationship of H_2S, Acid, Sulfate Reduction, and Methane Fermentation

Previous work on batch digestion of white water concentrate showed a deterioration of the seeding sludge upon subsequent additions of feed. To establish the relationship of gas production, volatile acid production, and sulfate reduction, a properly seeded mixture of white water was incubated for 10 days. Daily gas measurements, volatile acid determinations, and soluble sulfide analyses were made. After the 10-day incubation period the seed was used to inoculate a fresh batch of white water and the same analyses were conducted on the second passage.

* Paper of the Journal Series, New Jersey Agricultural Experiment Station.

The results (Figure 1) show that during the first passage the total volatile acid production reached a peak in 2 days and then decreased rapidly. Soluble sulfides increased rapidly for the first 7 days, thereafter remaining constant, with a maximum soluble sulfide concentration of 108 p.p.m. calculated as $S^{=}$. Sulfate reduction occurred gradually, but complete reduction was not accomplished in 10 days (about 60 per cent). Approximately 70 per cent of the B.O.D. was reduced in 10 days.

The results of the second passage (Figure 2) show that volatile acids increased rapidly for the first 3 days and then leveled off. The B.O.D. reduction during the second passage was 27 per cent. Sulfides increased rapidly and leveled off after 3 days of digestion, the final soluble sulfide being approximately 30 per cent lower than at the completion of the first passage. A 30 per cent reduction in total gas production occurred upon subsequent use of the seed sludge.

When the effluent from the second passage was aerated with CO_2 to remove sulfide and reseeded with fresh seed sludge, rapid gasification occurred (Figure 3) and volatile acids dropped to a low value. In the second passage approximately 600 p.p.m. of B.O.D. were reduced in 10 days; upon reseeding, 1,100 p.p.m. of B.O.D. were reduced in 4 days.

Comparison of the results of the first and second passages shows that the sludge used for a second passage de-

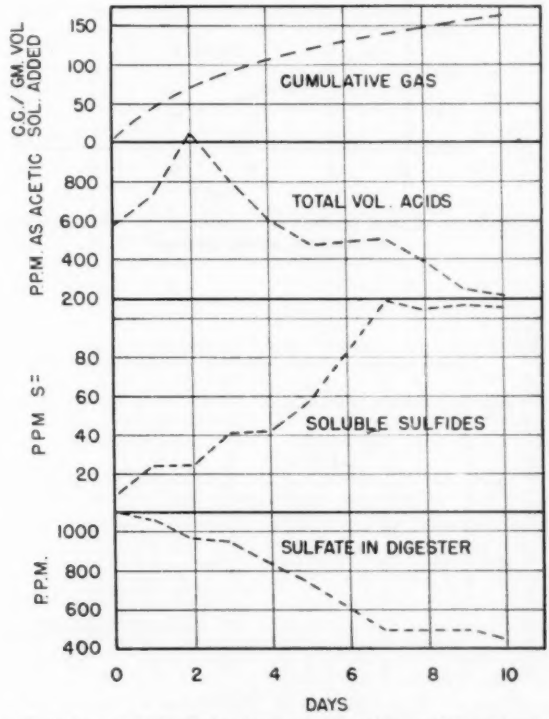

FIGURE 1.—Relation of H_2S production, volatile acids, sulfate reduction, and gas production; first passage.

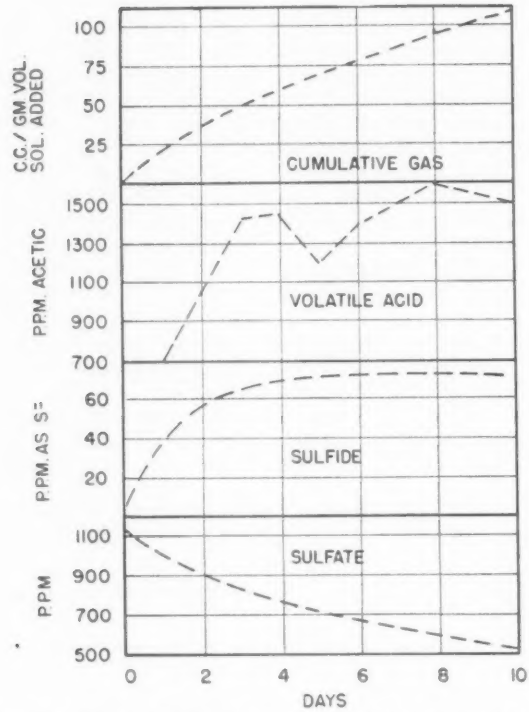

FIGURE 2.—Relation of H_2S production, volatile acids, sulfate reduction, and gas production; second passage.

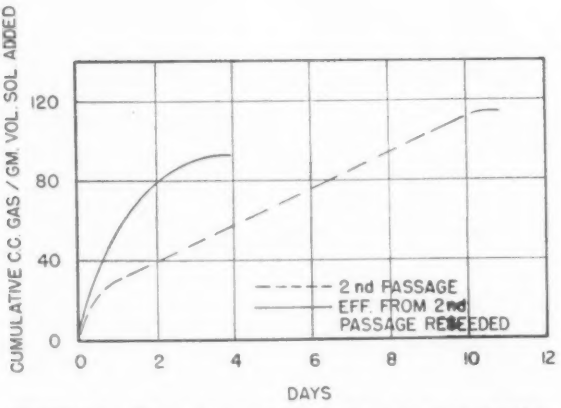

FIGURE 3.—Effect of reseeding and time on gas production.

teriorated and produced much less gas than the first. Under normal digestion conditions the volatile acid concentration increased slightly and then decreased to a low value, but when the acclimatized sludge was subjected to a second passage the volatile acids accumulated and were not reduced within practical limits of time. The results seemed to indicate that the high volatile acid concentration was responsible for the retardation, but reseeding of the effluent showed that this material, having a relatively high volatile acid concentration, was readily destroyed. Sulfides increased gradually during the first passage and reached a peak in about 7 days, at which time the major portion of the gas had been produced, whereas in the second passage the sulfides increased rapidly and gas production remained low; hence, a relationship appears to exist between high sulfide concentrations and low gas production. If the methane-producing bacteria are affected in the latter part of the first passage, the seeding value of the sludge for gas production would be appreciably reduced upon subsequent use.

Effect of Sodium Sulfide on Digestion of White Water Concentrate

To determine the effect of soluble sulfides upon digestion, various quantities of $Na_2S \cdot 9H_2O$ were added to the digestion mixtures. Sodium sulfide was used because preliminary experiments showed that it is difficult to obtain the desired concentration of sulfide by bubbling H_2S gas through the solution, and it is practically 100 per cent hydrolyzed at the pH values used in the digestion experiments.

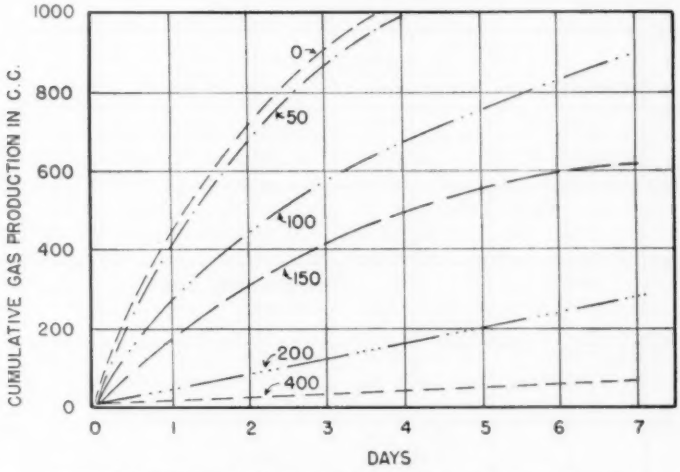

FIGURE 4.—Effect of sodium sulfide addition on gas production.

The effect of various concentrations of sodium sulfide (calculated as $S^=$) upon cumulative gas production is shown in Figure 4. Addition of soluble sulfide in excess of 50 p.p.m. as $S^=$ reduced gasification considerably.

A sharp decrease in total gas production and a more gradual decrease in volatile solids destruction are evident with increasing sulfide concentrations (Figure 5). A sulfide addition of 200 p.p.m. as $S^=$ resulted in only 20

per cent of the gas produced by the control mixtures, whereas lower sulfide additions showed a definite retardation in gas production. B.O.D. reductions were similarly affected.

Gas production, solids, and B.O.D. reductions indicate that soluble sulfides have a retarding or inhibitory effect upon the digestion of white water concentrate.

Effect of Sodium Sulfide on Digestion of Seeded Sewage Solids

Sodium sulfide has a retarding effect upon the digestion of white water concentrate and to determine whether this effect was specific for white water or held for other organic materials as well, various additions of sodium sulfide were made to properly seeded mixtures of fresh sewage solids.

Cumulative gas production data (Figure 6) show that increasing sulfide additions progressively retard gasification. Analytical results on volatile solids reductions show a similar decrease with increasing sulfide additions. Additions of 200 p.p.m. sulfides as $S^=$ decreased gas production about 70 per cent and volatile matter destruction more than 50 per cent. There is no doubt that sodium sulfide has a definite retarding effect upon the digestion of fresh sewage solids. The effect was more pronounced upon gas production than upon solids reductions.

Effect of Sodium Sulfide on Methane Fermentation

The digestion of complex organic compounds may be roughly divided into two stages: (a) acid production or liquefaction and (b) methane fermentation of the volatile acids. Inasmuch as volatile matter reduction is affected by certain concentrations of sulfide, it is conceivable that the effect of sulfides on gas production is secondary, because the complex organic material must be hydrolyzed and broken down to lower acids before the methane fermentation can proceed. Inhibition or retardation of the hydroly-

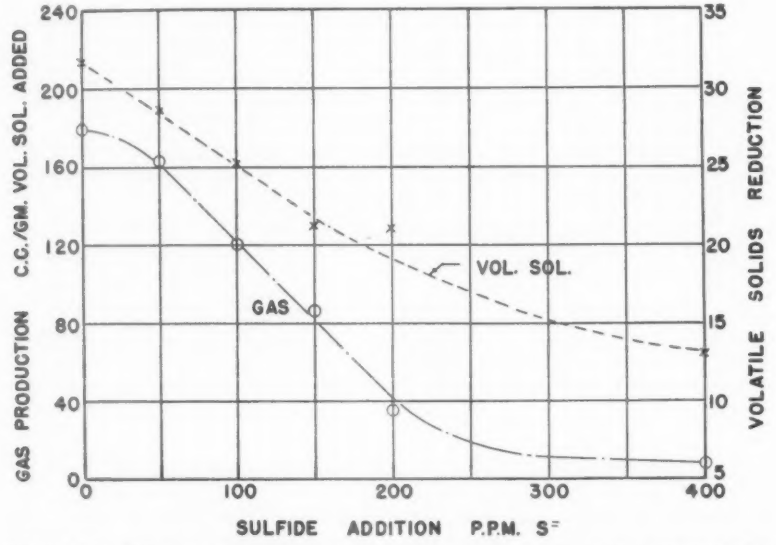

FIGURE 5.—Effect of sulfides on volatile solids reduction and cumulative gas production.

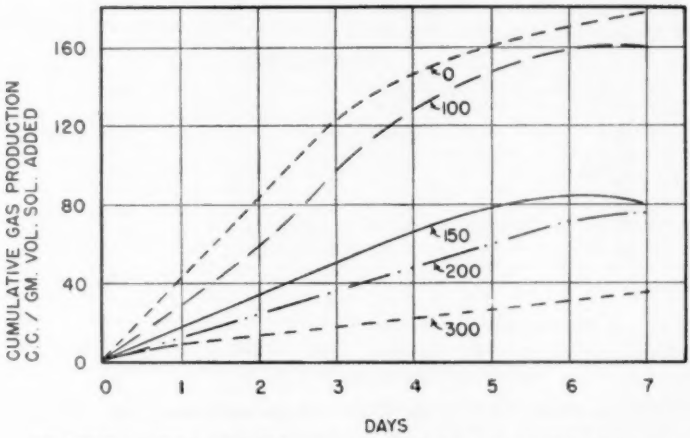

FIGURE 6.—Effect of sulfides on gas production of reseeded mixtures.

sis reactions would result in starvation of the methane-producing organisms.

Various concentrations of sodium sulfide were added to properly seeded solutions of sodium acetate as a substrate; hence, hydrolysis reactions were not involved, the acetate being utilized directly by the methane-producing bacteria.

Cumulative data (Figure 7) show that a rapid decrease in gas production occurred with increasing sulfide additions. Soluble sulfides decreased rapidly during the first 3 days, leveled off, and increased near the end of the experiment. B.O.D. and volatile acid reductions decreased rapidly with increasing sulfide additions (Figure 8). Approximately 21 to 34 per cent of the sulfide was lost upon adjustment of the pH of the feed to neutrality. During digestion the volatile acids were

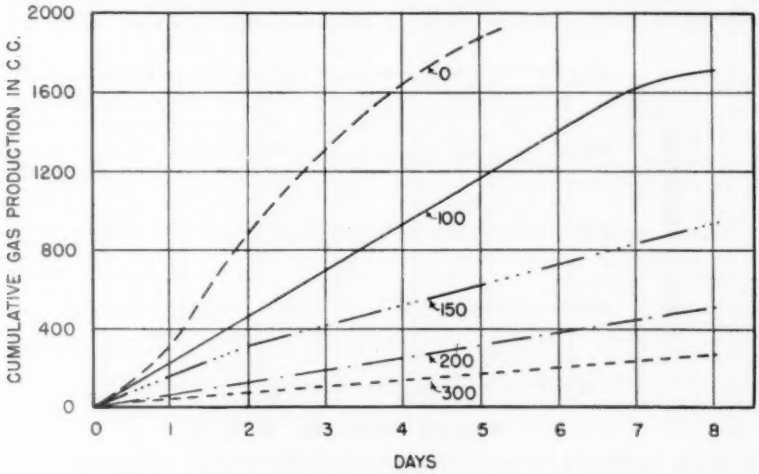

FIGURE 7.—Effect of sulfides on gas production from sodium acetate.

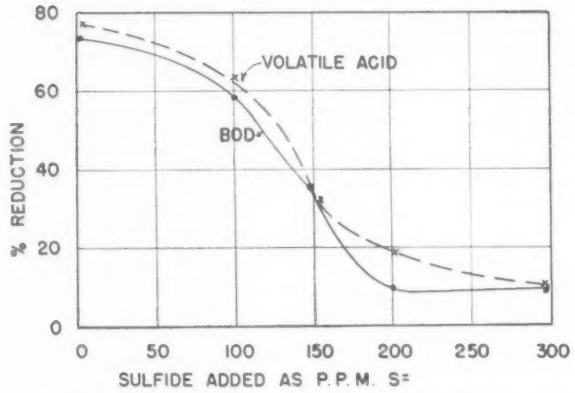

FIGURE 8.—Effect of sulfides on volatile acid production and B.O.D. reduction.

reduced by 9 per cent in the highest and by 77 per cent in the lowest concentration of sulfide added. Total gas production decreased with increasing quantities of sulfide additions, but not proportionally; for instance, sulfide addition of 82 p.p.m. $S^=$ decreased the total gas production by 33 per cent, whereas a concentration of 163 p.p.m. resulted in an 80 per cent reduction of the total gas production (Figure 9).

Because hydrolysis of the material used in this fermentation is not necessary, the acetic acid being utilized directly by the methane-producing bacteria, it is evident that sulfides affect the methane fermentation.

Effect of Sodium Sulfide on Hydrolysis of White Water Concentrate

To study the effect of sulfide on the hydrolysis reactions, sodium sulfide was added to improperly seeded mixtures of white water concentrate. Extremely small quantities of seed were used to prevent methane fermentation. The effect of various sulfide dosages was studied by determining volatile acids at various time intervals.

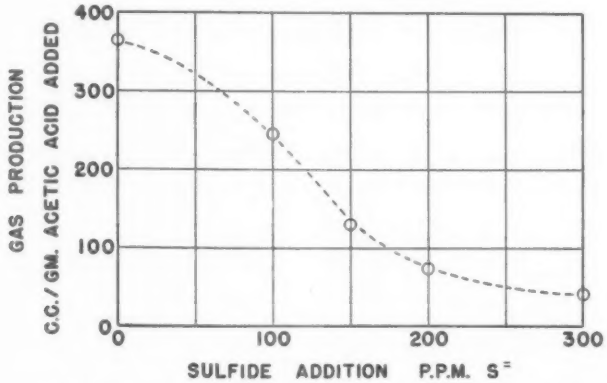

FIGURE 9.—Relation between sulfide addition to sodium acetate substrate and total gas production.

TABLE I.—Effect of Sulfide Upon Volatile Acid Production (Cumulative Total Volatile Acids as P.P.M. Acetic)

Time (days)	Sulfide Addition (p.p.m.)[1]				
	0	100	150	200	300
0	515	515	515	515	515
3	977	936	1,105	1,135	915
7	1,532	1,648	1,530	1,170	1,428
13	1,482	1,520	1,390	1,572	1,388
22	1,418	1,470	1,420	1,530	1,510
36	1,380	1,370	1,410	1,360	1,300

[1] As $S^=$.

The results of the volatile acid determinations show that the peak of volatile acid production was reached in approximately 7 days, and remained practically constant for the remainder of the run (Table I). No significant difference in acid production could be attributed to the sulfide additions.

The sulfide concentration remained fairly constant for the duration of the experiment, except for a slight increase toward the end. The sulfide additions used had little effect upon volatile acid production. It appears that sodium sulfide does not affect equally the two phases of digestion (hydrolysis and methane production).

Sulfate reduction reached a maximum when 150 p.p.m. $S^=$ were added to the digestion mixture, but with higher additions sulfate reduction decreased rapidly. Concentrations greater than about 150 p.p.m. $S^=$ appear to be toxic to sulfate reducers. This is indicated by the following values, which show the percentage total sulfate reduction at the end of the experiment with various amounts of sulfides added:

Sulfides Added (p.p.m. $S^=$)	Sulfate Reduction (%)
0	22.3
100	46.5
150	64.0
200	61.0
300	21.7

The increase in sulfide reduction up to 150 p.p.m. can be attributed to the lowering of the redox potential until the optimum potential was reached.

Discussion

In the anaerobic digestion of soluble organic wastes high in sulfate, considerable amounts of sulfides are produced. If H_2S is dissolved in water an ionization equilibrium is established represented by the equation:

$$H_2S \rightleftarrows H^+ + HS^-$$
$$HS^- \rightleftarrows H^+ + S^=$$

The second stage of ionization may lead to the formation of sulfide ion, but it is assumed that no significant amount of sulfide ion is formed below pH 12; hence, the second ionization is of no particular importance in digestion of sulfate-containing soluble organic wastes.

Preliminary experiments showed that it is difficult to obtain the desired concentration of sulfide by bubbling H_2S gas through the solution; hence, $Na_2S \cdot 9H_2O$ was used. Sodium sulfide is practically 100 per cent hydrolyzed at the hydrogen ion concentration used in digestion (pH 7.0). Part of the sulfide added was not recoverable (approximately 21 to 34 per cent), either through the formation of insoluble sulfides, or through being driven off as H_2S upon adjustment of the pH of the feed to neutrality.

When the effect of soluble sulfide concentrations in the digestion mixtures upon gas production is expressed as a percentage of the gas produced without sulfide addition, the results indicate (Figure 10) that the decrease in gas production for the methane fermentation of acetate decreases directly with sulfide concentration. There appears to be a clear-cut break at about 165 p.p.m. sulfide as $S^=$ addition. A small amount of gas was produced with every higher sulfide addition, amounting to about 10 per cent of the gas produced by the control mixtures. If it is kept in mind that the total gas produced in the control

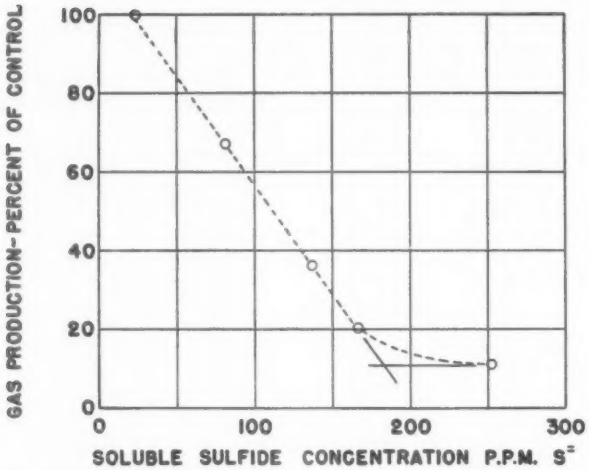

FIGURE 10.—Linear relationship between soluble sulfides and gas production.

mixtures contained about 20 per cent carbon dioxide, and that other experiments have shown that the percentage of carbon dioxide during the first phases of digestion and during periods of poor digestion is very high (sometimes the gas produced consists of CO_2 only), it may be assumed that practically no methane was present when more than 165 p.p.m. $S^=$ was added. Hence, it appears that the methane-producing organisms are progressively affected by increasing quantities of sulfides, and that methane fermentation is a linear function of the sulfide concentration.

The addition of sulfide to improperly seeded mixtures of white water showed that acid production was not affected by sulfide additions up to 300 p.p.m. $S^=$. Since the effect of sulfides is much more pronounced upon the methane producers than upon the acid producers, an accumulation of volatile acids can be expected. Failure to consider the sulfide may lead to the erroneous conclusion that the volatile acids were the cause of failure. It becomes apparent that the increase in volatile acids was caused by the soluble sulfide concentration which prevented utilization of the volatile acids by the methane-producing organisms.

During the normal course of digestion, the volatile acids increased, then rapidly decreased, and soluble sulfides gradually increased to a peak after approximately 6 days of digestion. Use of seed previously exposed to a sulfide concentration of 100 p.p.m. to inoculate a fresh batch of white water resulted in a rapid increase in volatile acids and a reduction in gas production.

It is evident that the accumulation of acids is not the primary cause of digestion failure, but it may be a secondary factor if the hydrogen ion concentration drops too low. In the digestion of wastes high in sulfates, it then becomes apparent that the soluble sulfide determination would be of greater value as a control measure than the volatile acid determination, as an increase in soluble sulfides will be detected much sooner than any change in the acid content.

Buswell (3) states that the accumulation of organic acids and their salts to the extent of 2,000 to 6,000 p.p.m.

acetic overtaxes the buffer capacity of the medium, and increasing the buffer capacity by the addition of alkalies aggravates the situation. It is logical that, if the accumulation of acids is caused by sulfides in solution, the addition of alkali will aggravate the situation, because a higher concentration of sulfide can be held in solution at the higher pH value. It has also been shown that properly seeded acetate is readily fermented in concentrations as high as 4,000 p.p.m., as acetic, in the absence of sulfides and that the destruction of the acetate rapidly decreases with increasing sulfide concentrations.

Conclusions

From the experimental data obtained the following conclusions have been drawn:

1. Sodium sulfide added to properly seeded white water and sewage solids results in inhibition of gasification at concentration of 150 to 200 p.p.m. calculated as $S^=$, and retardation of gasification at relatively low sulfide concentrations.

2. Soluble sulfides are toxic to the methane fermentation of sodium acetate when a concentration of about 140 p.p.m. as $S^=$ is reached, and lower sulfide concentrations result in retardation of the fermentation.

3. Sulfide concentrations up to 300 p.p.m. as $S^=$ have no apparent effect upon the liquefaction reactions. The differential effect of sulfides upon the two phases of digestion (acid production and methane fermentation) will result in an accumulation of volatile acids and ultimate failure of the fermentation.

Summary

In the anaerobic stabilization of soluble organic wastes high in sulfate, considerable quantities of hydrogen sulfide are produced. Laboratory studies to determine the effect of various concentrations of soluble sulfide upon the anaerobic digestion process showed that additions of sodium sulfide up to 300 p.p.m. (as $S^=$) had no effect upon the production of volatile acids when a complex substrate such as white water concentrate is used. A soluble sulfide concentration as low as 82 p.p.m. $S^=$ retarded the methane fermentation of sodium acetate, and soluble sulfide concentrations in excess of 150 p.p.m. $S^=$ practically inhibited methane fermentation.

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Stream Pollution

POLLUTION STUDY OF THE MAUMEE RIVER BASIN *

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A detailed water pollution study of the Maumee River Basin has been a part of a long-range program looking toward the abatement and the control of water pollution in Ohio. The merit of river basin approach to pollution evaluation, although initiated a number of years ago, is emphasized by the now rather universally accepted concept of restoring and protecting waterways for uses which, in the public interest, are reasonable and necessary.

A study of this kind has several purposes, as follows:

1. It catalogues all significant sources of pollution in the basin.
2. It makes possible the definitions of wastes and the evaluations of pollution loads.
3. It provides measurements of the effects of these loads on the waterways under hydrological, temperature, and other pertinent conditions encountered during the period of the survey.
4. It furnishes a basis for projecting these loads to critical stream flows.
5. It makes available data for determining the extent to which pollution loads must be reduced, verifying or offering guidance in the adjustment of tentative decisions that must frequently be made relative to degrees of treatment or to waste reductions in advance of detailed studies.

Although not related to the engineering or technical fact-finding, such a study also affords an opportunity to educate municipal officials and industrial managements with respect to their responsibilities of defining and evaluating wastes and to the need of initiating comprehensive corrective programs.

The Maumee River is an interstate stream. To correlate the efforts of Ohio with the federal program initiated and carried on under the provisions of Public Law 845, and by reason of the importance of this area as related to other major sub-basins in the state, it was expedient that this study be made among the first. Consequently, during the summer and fall months of 1950 the major part of the field work in the Ohio area was accomplished by the Water Pollution Control Unit of the Sanitary Engineering Division, Ohio Department of Health. Stream studies and some special industrial wastes studies were carried over into the spring and summer of 1951. The principal reason for prolonging the field work was that the 1950 rainfall and stream flows were so much above normal as to make it impractical to attempt to apply analytical data to stream sanitation formulas.

Considering the importance of the interstate aspect, the cooperation of the Indiana Stream Pollution Control Board was sought. Personnel of that agency most willingly arranged to collect field data in the Indiana area comparable to that planned for Ohio so as to make the final study consistent throughout the basin. The field work

* Presented at 26th Annual Meeting, Ohio Sewage and Industrial Wastes Treatment Conference; Toledo, Ohio; May 21–23, 1952.

was correlated to the extent that stream sampling on at least one occasion was done simultaneously on the Ohio and Indiana sections of streams having direct interstate significance. Likewise, methods of analyses were correlated to obtain as truly representative a picture as possible.

Personnel of the Ohio-Tennessee Basins Office, Division of Water Pollution Control, U. S. Public Health Service, have shown much interest in the study. In fact, that office has assisted materially in the correlation of data for an over-all basin report and has actively participated in the preparation of the final report. It is anticipated that the report not only will serve the respective needs of Ohio and Indiana with respect to a long-range program of water pollution abatement and control, but also will be adopted by the Surgeon General as meeting his requirements for a comprehensive water pollution control program under the provisions of Public Law 845.

Description of Basin

The Maumee River (Figure 1), a tributary of Lake Erie, drains an area of 6,586 sq. mi., of which 4,856 sq. mi. are in Ohio, 1,260 sq. mi. are in In-

FIGURE 1.—Drainage pattern and location of Maumee River Basin.

diana, and 470 sq. mi. are in Michigan. The Maumee River has its source at Ft. Wayne, Ind., where its two major tributaries, the St. Marys and St. Joseph Rivers, come together. From its head at Ft. Wayne to its mouth in the western end of Lake Erie the Maumee River is about 150 mi. long and has a total fall of about 165 ft., an average fall of 1.1 ft. per mile. That part of the Maumee in Ohio is about 110 mi. in length.

The St. Marys River, originating in Shelby County, Ohio, flows northwestward for about 100 mi. with an average gradient of approximately 2.5 ft. per mile. The St. Joseph River, also about 100 mi. long, has its origin in Hillsdale County, Mich., and flows across the northwest corner of Ohio, entering Indiana about 35 mi. northeast of Ft. Wayne. The St. Joseph has a gradient of about 3.1 ft. per mile.

Two more large tributaries join the Maumee River at Defiance. The Tiffin River enters from the north, the Auglaize from the south. The Blanchard and Ottawa Rivers are important tributaries of the Auglaize River.

Population Distribution

Based on the 1950 census figures, the population of the Maumee watershed was about 948,600. Ohio had 698,600, Indiana 223,400, and Michigan 26,600 inhabitants, or approximately 74, 23, and 3 per cent, respectively, of the total for the basin. The Ohio figure includes the entire population of Toledo. Although this city is only partly within the basin, its waste disposal facilities discharge to the Maumee River. For this reason, all of Toledo is considered to be within the basin for purposes of this study.

The average population density of the Maumee River Basin is approximately 144 persons per square mile. About 689,800, almost three-fourths of the total, are concentrated in 129 incorporated cities and towns. This population of incorporated communities includes all such places listed in the 1950 report of the Bureau of the Census. Of this population in incorporated places, 487,469 are found in the three cities of Toledo and Lima, Ohio, and Ft. Wayne, Ind.

Industries

This basin is an important agricultural area, but manufacturing is of considerable significance in the larger cities.

The greater portion of the land of the basin is under cultivation. Diversified farming, dairying, and some stock raising are practiced. Industrial activities in the basin are also varied. Manufactured products include locomotives, automobiles and trucks, machinery, electrical equipment, processed foods, beet sugar, refined oil products, and many others. Oil fields in the eastern portion of the basin have passed their peak of productivity, but wells are still pumped periodically. Natural gas produced in substantial quantities in the area is piped to metropolitan centers for domestic and commercial consumption. Lima, Ohio, is the center of an oil distribution system with pipe lines from the oil fields of Wyoming, Texas, and Oklahoma. Toledo, Ohio, besides being a railroad center and a very important coal shipping one, supports varied industrial activities.

Water Uses Within the Basin

The surface waters of the Maumee River Basin are used for public water supplies, industrial supplies, fish and wildlife propagation, recreation, navigation, hydroelectric power, and the disposal of municipal and industrial wastes.

The use of the river and its tributaries for public water supply purposes is probably the most important. There are 75 public water supplies, both ground and surface, serving 79 municipalities representing 707,300 people. Although the city of Toledo obtains its

water from Lake Erie, it is included because the quality of the raw water is affected by pollution entering the lake by way of the Maumee River. This municipal system serves the city of Toledo, two other small municipalities, and certain Lucas and Wood County areas representing a total population of about 300,000 people. It is interesting to note that Bowling Green, located outside of the drainage basin, has found it expedient to obtain water from the Maumee River and hence is included in the total population served by public supplies.

Of the 75 public supplies, there are 14 water treatment plants using the Maumee River and its tributaries as

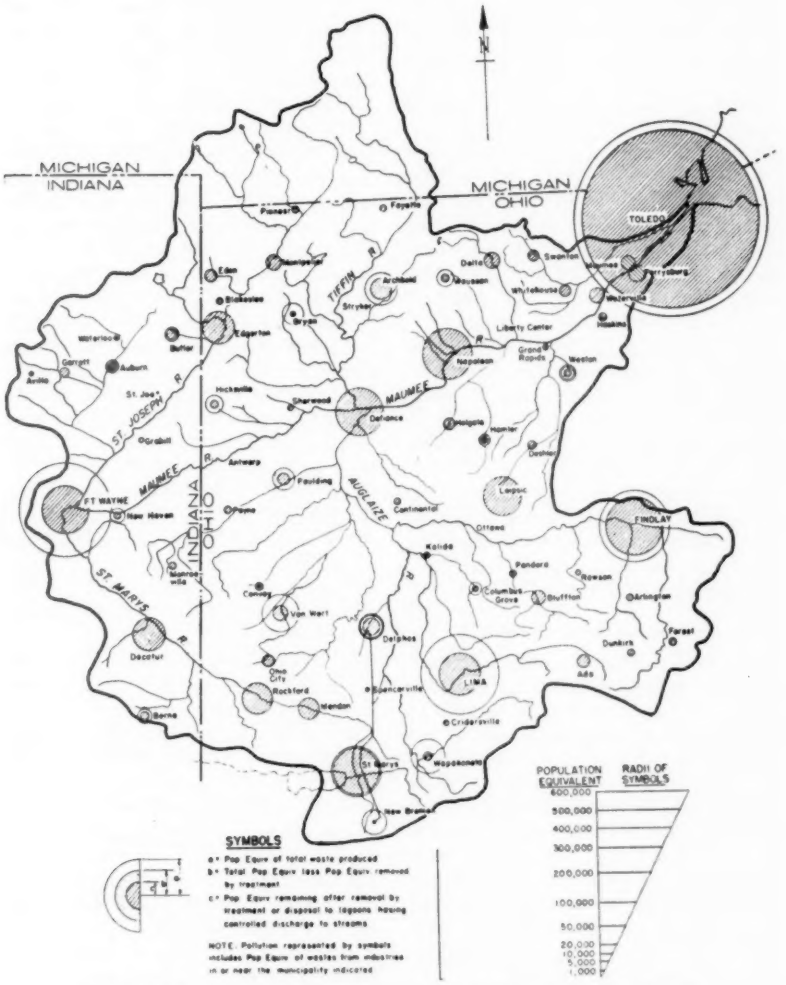

FIGURE 2.—Major pollutional contributions of Maumee River Basin.

sources of raw water serving 18 municipalities with total population of 591,500. Consequently, 84 per cent of the municipal population served by public water supplies depends on surface water. This is indeed significant, revealing that ground water of sufficient quantity and of satisfactory quality can be depended upon only by the small communities with relatively low daily requirements. The largest municipality in the basin served by ground supply is Decatur, Ind., population 7,271.

Perhaps the potential recreational value of basin waters is not fully indicated by present uses. Some waters now are used for boating, fishing, and other recreation. For instance, an annual boat regatta is held on the Maumee River below Ft. Wayne, Ind. Bass, catfish, blue gills, and other species of pan fish in significant numbers are caught in waters of the basin.

Navigation is an important use in the lower reaches of the Maumee River. A 7-mi. channel extending up the river from deep Lake Erie water serves as a connecting link between lake shipping and railroad facilities.

This brief summary of essential water uses indicates the need of reducing the pollution caused by municipal and industrial wastes to extents that will be consistent with the public interest.

Pollution Distribution

It is pertinent to present the distribution of the organic or deoxygenating pollution as evaluated. Figure 2 shows graphically the pollution loads of deoxygenating significance both before any treatment or reduction is made and as discharged. The focal points of concentration are thus clearly identified. It will be noted that the small area in Michigan has not been covered. This seemed to be warranted, insofar as investigations indicated that pollution of this area is relatively insignificant to the basin as a whole.

Of the total population (948,700) in the basin area, Ohio contributes 698,800, Indiana 223,400, and Michigan 26,500, or 74, 23, and 3 per cent, respectively. About 73 per cent of the combined population of Ohio and Indiana (922,200) is urban. The total measurable sewered population equivalent load, before treatment or reduction, of the combined Ohio and Indiana areas has been estimated to be 1,517,000 (901,700 municipal and 613,300 industrial); that discharged, 968,100 (486,900 municipal and 481,200 industrial). In a long-range program there can well be added to the sewered population equivalent before treatment a potential increment of about 17,000. This generally represents small municipalities provided with public water supplies but not with comprehensive sewage collection systems. For the most part these problems hold no immediate significance, but they cannot be entirely overlooked. Pollution reduction based on population equivalent B.O.D. that was being accomplished at the time of the investigation amounted to about 35 per cent (municipal reduction about 42 per cent; industrial, about 22 per cent). Also, from the foregoing figures responsibility for the over-all loads is in the ratio of 59.5 per cent municipal to 40.5 per cent industrial. For discharged loads the ratio is 51.3 per cent municipal to 49.7 per cent industrial.

In considering these figures it is significant that industrial wastes which were tributary to municipal sewers were not generally evaluated individually but were reflected only in the characteristics of municipal sewage, and that the per cent reductions of the over-all industrial pollution load may not in all cases give full value to corrective measures that have been accomplished by good housekeeping, by waste elimination through changes of process, etc. Industrial pollution having deoxygenating significance within the Maumee River Basin is given in Table I.

TABLE I.—Industrial Pollution Having Deoxygenating Significance in Maumee River Basin

Type of Industry	Plants Investigated	Pop. Eq. of Wastes as Discharged
Ohio:		
Paper	1	18,800
Meat	10	12,317
Milk	6	4,919
Canning	17[1]	111,456
Oil refining	6	124,640
Sugar beet	2	77,840
Coke by-product	1	83,732
Miscellaneous	10	24,419
Total	53	458,123
Indiana:		
Meat	2	6,480
Milk	2	780
Canning	3[2]	300
Soya processing	1	6,040
Miscellaneous	1	9,500
Total	9	23,100
Grand Total	62	481,223

[1] 5 lagoons. [2] 2 lagoons.

Full cognizance was taken of inorganic industrial wastes and of other wastes that have properties other than deoxygenating and that fall in categories such as taste and odor, toxic, etc. Some may fall in several categories. Significant inorganic wastes were produced by 9 metal finishing establishments, 1 blast furnace, and 1 foundry. Wastes from metal finishing fall largely in the toxic category. Industrial establishments, the wastes from which must be considered for other properties as well as oxygen consuming, comprised 6 oil refineries, 2 industrial plants producing oily wastes by reason of process, and 1 by-product coke plant.

Hydrological Aspects

Stream flows experienced in the Maumee River and its tributaries during the 1950 field survey were three or four times those normally experienced. In the late summer of 1951 flows more nearly approached, but never reached, drought proportions. Even so, on tributary streams the effects of pollution loads could be observed satisfactorily and conclusions drawn with little difficulty. On the main stem of the Maumee River, however, it was not so easy. Other than experiencing relatively high flows, physical features such as dams interfered with satisfactory observations relative to the response of the river to pollution loads under drought conditions.

A thorough study of all flows of record was made at key U. S. Geological Survey stations located within the basin. These stations were St. Marys River at Ft. Wayne, St. Joseph River at Ft. Wayne, Tiffin River at Stryker, Auglaize River at Ft. Jennings, Blanchard River at Findlay, Maumee River at Waterville, Maumee River at Defiance, and Maumee River at Antwerp. Flow records extended over periods of 9 to 35 years at the several stations.

Frequency curves were developed from records of respective gaging stations to show per cent of years when minimum monthly averages, minimum seven-consecutive-day averages, and minimum daily flows were greater than those shown. Conversely, the curves show the per cent of years when the specified minimum flows were equal to or less than those shown. Figure 3 is a typical curve. It will be noted that for 80 per cent of the years the minimum average monthly, the minimum average seven-consecutive-days, and the minimum daily flows were equal to or greater than 170, 112, and 70 c.f.s., respectively. Conversely, in 20 per cent of the years these minimums will equal or be less than the values shown. This is a measure of probability and by no means infers that there will be occurrences of low flows in regular sequences. However, a study of the respective curves, together with other methods of analyzing flow data, prompted the selection of a "critical"

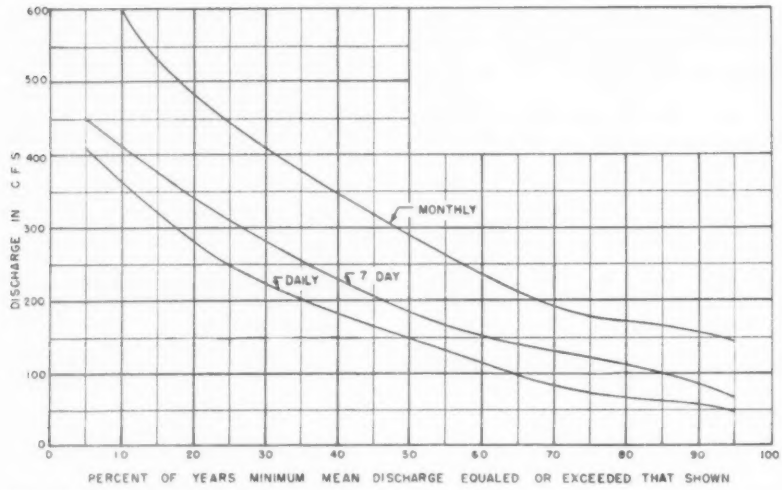

FIGURE 3.—Low-flow frequency curves for Maumee River at Waterville, Ohio, for years 1922–35 and 1939–50.

flow to be used as a criterion in the reduction of pollution loads. For the Maumee River Basin this critical flow is a minimum seven-consecutive-days average flow which or less than which will probably occur in 20 per cent of the years. The minimum seven-consecutive-day average flow was selected as critical for the reason that a condition more or less constant for that period of time results in serious effects. The 20 per cent frequency appears satisfactory for basin conditions and should afford reasonable protection for essential water uses.

Critical flows at gaging points were, therefore, established (Table II). It will be noted that yields per square mile were developed from the respective minimum seven-day average flows and the drainage area at the location of each station. Considerable variance in yield per square mile is noted at the various locations. For instance, the yield of 0.0612 c.f.s. per sq. mi. for the St. Joseph River at Ft. Wayne indicates that there must be considerable recharging of the stream from underground storage. Contrary to this, the yield of the Blanchard River at Findlay is relatively low and is typical of the conditions at the headwaters

TABLE II.—Critical Flows Established at Gaging Points on Maumee River and Tributaries

Stream	Location	Min. 7-Day Av. Flow (c.f.s.)	Drainage Area (sq. mi.)	Yield Per Sq. Mi. (c.f.s.)
St. Marys	Ft. Wayne, Ind.	10.0	753	0.0133
St. Joseph	Ft. Wayne, Ind.	65.0	1,060	0.0612
Tiffin	Stryker, Ohio	13.0	444	0.0293
Auglaize	Ft. Jennings, Ohio	11.0	333	0.033
Blanchard	Findlay, Ohio	2.5	343	0.0073
Maumee	Waterville, Ohio	112	6,314	0.0177
Maumee	Defiance, Ohio	90	5,530	0.0163
Maumee	Antwerp, Ohio	87	2,049	0.0425

TABLE III.—Critical Flows at Focal Points on the Auglaize River and Its Tributaries

Location	Drainage Area (sq. mi.)	Yield Per Sq. Mi.[1] (c.f.s.)	Critical Flow[2] (c.f.s.)
Fort Jennings	315	0.033	10.4
Wapakoneta	108	0.033	3.6
Continental	3.3	0.033	0.11
Paulding	93.6	0.033	3.1
Payne	33.5	0.033	1.10
Van Wert	34.9	0.033	1.15
Ohio City	5.0	0.033	0.165
Ottawa	632	0.033	21
Findlay	343	0.0073	2.5
Forest	2.9	0.033	0.095
Dunkirk	3.0	0.033	0.099
Pandora	80.9	0.003	2.7
Bluffton	70.8	0.033	2.3
Arlington	6.8	0.033	0.22
Kalida	315	0.033	10.4
Lima	133	0.033	4.4
Columbus Grove	24.2	0.033	0.80
Ada	12.5	0.033	0.41
Delphos	74.3	0.033	2.5
Spencerville	3.5	0.033	0.115

[1] All based on Fort Jennings gaging station except Findlay, based on Findlay gaging station.

[2] Minimum 7-day average flows expected to be exceeded in 80 per cent of the years.

of this stream. There can be little recharging from underground storage.

Using the yield per square mile at gaging stations, the critical flows (seven-consecutive-day flows), which or less than which will occur 20 per cent of the years, were computed for focal points in the area. The curve used was that for the gaging station which seemed to represent best the conditions at a focal point. In all cases, therefore, the yield at a focal point is not referred to the gaging station in the immediate tributary drainage area of the focal point. Tables III, IV, and V give the yield and critical flow data for the focal points on the Auglaize River; the Tiffin, St. Marys, and St. Joseph rivers; and the Maumee River and its minor tributaries, respectively.

Water Quality Objectives

The basic objective of the proposed program for abatement and prevention of pollution in the Maumee River Basin is to secure and maintain a water quality in the various streams and sections of streams suitable for those uses which, in the public interest, are reasonable and necessary.

Establishment of treatment requirements, or other corrective measures, for wastes discharged to the streams involves the proper correlation of several factors so that the final waste effluents will be consistent with the basic objective. The factors involved include quality and quantity of wastes discharged, dilution and natural purification capacities of the receiving streams, water uses, population and industrial growth trends, economic balances between pollution abatement costs and benefits received, and qual-

TABLE IV.—Critical Flows at Focal Points on the Tiffin, St. Marys, and St. Joseph Rivers and Their Tributaries

Location	Drainage Area (sq. mi.)	Yield Per Sq. Mi.[1] (c.f.s.)	Critical Flow[2] (c.f.s.)
(*a*) Tiffin River			
Stryker	444	0.0293	13.0
Bryan	10.2	0.0293	0.30
Archbold	2.0	0.0293	0.059
West Unity	1.7	0.0293	0.050
Fayette	13.6	0.0293	0.40
(*b*) St. Marys River			
Rockford	314	0.0133	4.2
Mendon	259	0.0133	3.4
St. Marys	150	0.0133	2.0
New Bremen	3.87	0.0133	0.051
(*c*) St. Joseph River			
Edgerton	436.4	0.0612	27
Montpelier	329.4	0.0612	20
Blakeslee	23.2	0.0612	1.42
Edon	11.1	0.0612	0.68
Pioneer	28.5	0.0612	1.75

[1] Tiffin River based on Stryker gaging station; St. Marys and St. Joseph Rivers based on Fort Wayne gaging stations.

[2] Minimum 7-day average flows expected to be exceeded in 80 per cent of the years.

TABLE V.—Critical Flows at Focal Points on the Maumee River and Its Minor Tributaries

Location	Drainage Area (sq. mi.)	Yield Per Sq. Mi. (c.f.s.)	Critical Flow[1] (c.f.s.)
Toledo	6,586	0.0177[2]	117.6
Perrysburg	6,335	0.0177[2]	112
Maumee	6,331	0.0177[2]	112
Waterville	6,314	0.0177[2]	112
Grand Rapids	6,055	0.0177[2]	107
Texas	5,936	0.0177[2]	105
Napoleon	5,642	0.0163[3]	92
Defiance	5,510	0.0163[3]	90
Antwerp	2,049	0.0425[4]	87
Whitehouse	1.77	0.0293[5]	0.052
Swanton	24.7	0.0293[5]	0.72
Weston	8.7	0.033[6]	0.29
Leipsic	4.0	0.033[6]	0.13
Delta	50	0.0293[5]	1.47
Wauseon	6.1	0.0293[5]	0.18
Holgate	14.0	0.033[6]	0.46
Hamler	25.4	0.033[6]	0.84
Liberty Center	24.0	0.0293[5]	0.70
Sherwood	12.5	0.0425[4]	0.53
Hicksville	5.1	0.0425[4]	0.22

[1] Minimum 7-day average flows expected to be exceeded in 80 per cent of the years.
[2] Based on Waterville gaging station.
[3] Based on Defiance gaging station.
[4] Based on Antwerp gaging station.
[5] Based on Stryker gaging station.
[6] Based on Ft. Jennings gaging station.

ity of water required for the various uses.

The water pollution survey by the states and information from other sources provide data on wastes discharged, stream flows, population trends, and water uses which are presented elsewhere in the report. This section is concerned primarily with water quality objectives to be applied in correlation with other factors.

It is recognized that the water uses may vary for different streams and for different sections of a particular stream. Furthermore, the maximum allowable concentrations of polluting substances will vary with the different water uses and the effects of a particular substance may also vary depending on the presence or absence of other substances in the receiving waters.

It is also recognized that consideration must be given to the economic balance between the cost of pollution prevention or abatement and the benefits received. This balance is not necessarily the same for reclamation of polluted waters as for the preservation of relatively unpolluted water; consequently, water quality objectives formulated on the basis of restoring a polluted stream or section of a stream to a minimum quality consistent with downstream water uses cannot be considered as inviting the lowering of the water quality throughout the basin.

In the application of water quality objectives consideration must be given to provision for proper sharing of water resources, provision for future development, and other special needs in the public interest. For example, minimum correction of an upstream waste discharge to comply with maximum permissible concentration at that point could result in the usurpation of the capacity of the stream for many miles to the unfair disadvantage of existing or potential downstream discharges of the same or a similar waste. Use of the surface waters of the basin for public water supplies is a high-priority need. Water quality objectives, designed to meet the requirements of this use, will be applied to protect existing and future supplies.

For the reasons discussed, water quality objectives established to maintain the basin's waters in a condition suitable for reasonable and necessary uses must be sufficiently flexible to meet the varying conditions which exist. Limits for polluting wastes given in the following paragraphs are considered the maximum permissible for a minimum quality of water. They are to serve as guides in determining pollution abatement control measures, but more restrictive limits may be required if consideration of all factors at specific locations shows a higher quality of water to be needed in the public interest.

In considering water quality objectives, pollution may be classified on the basis of effects on water quality as follows: bacterial contamination, deoxygenation, toxicity, taste and odor, color, undesirable pH conditions, suspended solids and floating material, excessive dissolved solids, and high temperature.

Bacterial

Bacterial pollution usually is associated with domestic sewage. This is understandable by reason of the disease organisms that may be contained in human excretions. However, bacterial increases are coincident with organic decomposition and bacterial concentrations will vary with organic content and with stages of deoxygenation and decomposition. Bacterial quality is definitely pertinent to the uses of water for public water supply and for recreational purposes. The densities of coliform organisms furnish accepted criteria for the evaluation of public supply and recreational waters. The most probable number method of enumeration (MPN) is used by the Indiana Stream Pollution Control Board. The Ohio Department of Health is prone to use the indicated number (IN) based on Phelps Index values, as a time-saving procedure. Although the two methods of calculation are different and although identical results are not obtained when they are applied, respectively, to the same data, the differences in values obtained are of minor significance. For all practical purposes coliform density requirements of the same numerical values expressed either as MPN or as IN result in the same degrees of water treatment.

At waterworks intakes on waters of the Maumee River Basin the monthly arithmetical average MPN or IN of coliform organisms should not exceed 5,000 per 100 ml. in any month; nor exceed this density in more than 20 per cent of the samples of such waters examined during any month; nor exceed 20,000 per 100 ml. in more than 5 per cent of such samples. It is felt that if coliform reductions are accomplished to attain such quality, accepted practices of water treatment will insure safe public supplies.

Meeting this objective for public water supplies at presently established intakes will insure stream zones for certain recreational purposes and may establish a few stream areas of water quality suitable for bathing or swimming. For non-bathing or non-swimming recreation the monthly arithmetical average MPN or IN should not exceed 5,000 per 100 ml. in any month of the recreational season, nor should exceed this number in more than 20 per cent of the samples examined during such month. For bathing and swimming waters the monthly arithmetical average MPN or IN of coliform organisms should not exceed 1,000 per 100 ml.; nor should exceed this number in more than 20 per cent of the samples examined in such month; nor should exceed 2,400 per 100 ml. on any one day. It must be emphasized, however, that even though all bacteria from sewage pollution were to be removed, other factors beyond the control of water pollution control agencies may still make waters of the inland streams of the basin unsuitable for bathing. Careful consideration must be given to natural, public health, and economic factors in justifying the application of bathing water quality objectives to waters of the basin.

Deoxygenation

Deoxygenating wastes are usually organic in nature, containing material either in suspension or solution, and may derive from sanitary sewage or from industrial wastes. Where organic pollution is sufficiently great, the oxygen content of the water is depleted; the propagation of fish and other wildlife is inhibited or they are killed; oxidation ceases; and anaerobic decomposition or septic action increases.

with attendant nuisances, disagreeable odors, toxic effects, and public health menaces. Adequate protection of the waters against unreasonable oxygen depletion should result if sufficient treatment is provided sewage and industrial wastes for substantially complete removal of settleable solids together with sufficient removal of other organic matter so as to hold the dissolved oxygen content above a critical point. The minimum dissolved oxygen content for the Maumee River and its tributaries has been established at 4 p.p.m., which during critical summer conditions is comparable to 50 per cent dissolved oxygen saturation. This criterion meets requirements of normal water uses, including the protection of fish and wildlife common to the waters of the basin. Exceptions are made where water uses require higher quality.

Toxic Wastes

There are literally hundreds of substances, alone or in combination, which at critical concentrations are toxic to humans, animals, fish, and other wildlife. The toxic effects may range from serious conditions affecting public health and/or causing direct fish kills to minor disturbances which may be serious only over a long period.

The chemical characteristics or mineral content of the receiving water have a great influence on the toxicity of individual pollutants to fish and aquatic life. Also, concentrations of certain substances, considered individually, may not be serious, whereas they may be quite injurious in combination with other substances.

In some instances concentrations of toxic materials not sufficient to cause direct kills of fish but inimical to their propagation possibly may be tolerated in short, most critical, stream sections. Concentrations causing direct kills will not be permitted in any streams of the basin.

The preceding discussion results in the conclusion that it is impractical to fix definite limits on concentrations of toxic substances. The general objective will be to eliminate or prevent concentrations which will be unduly injurious to the reasonable and necessary uses. Insofar as fish and other aquatic life are concerned, determination of whether or not the objective is being met will be based on biological indices of pollution. Application of toxicity limits to protect fish and other aquatic life will generally provide satisfactory protection for other water uses. Should there be exceptions, limits will be based on the specific uses affected.

Although, as previously mentioned, there are many substances and combinations of substances which are toxic, it is likely that a great many of these will not be discharged to the streams in sufficient quantity to be a problem, possibly because such wastes are not normally found in the basin or because their value tends to preclude their discharge as waste products. However, some substances encountered during this investigation have been and are proving troublesome to certain uses in concentrations above certain limits. Occurrence of these substances above such limits will be prima facie evidence that excessive pollution exists. Pending the results of studies and research now in progress by qualified technical groups, the following should serve as a guide to the reasonable protection of the waters of the basin:

Cyanide (as CN)	not over 0.15	p.p.m.
Lead (as Pb)	not over 0.35	p.p.m.
Copper (as Cu)	not over 0.4	p.p.m.
Chromium (hexavalent) (as Cr)	not over 2.0	p.p.m.
Cadmium (as Cd)	not over 0.4	p.p.m.
Zinc (as Zn)	not over 1	p.p.m.
Nickel (as Ni)	not over 5	p.p.m.
Nitrate (as N)	not over 10	p.p.m.

It is emphasized that exceptions to these limits must be made where water uses require higher quality; and, fur-

ther, that some of the substances mentioned may cause damage in lower concentrations than noted under certain conditions and in certain combinations.

Taste and Odor

In general, wastes producing tastes and odors shall be limited to the extent required to prevent undue damage to reasonable and necessary water uses.

Probably the most prevalent offensive wastes from the standpoint of tastes and odors are the phenolic wastes from coke, synthetic resin, synthetic fiber and rubber, oil refining, petroleum, tar cracking, road oil, creosoting, wood distillation, and dye manufacturing industries. The limits each for phenol, oil, and allied derivatives shall be substantially complete removal at their sources.

Color

Color-producing substances causing impairment of reasonable and necessary water uses will not be permitted.

At least partially pertinent to this category are iron and manganese. If an objective of 5 p.p.m. (as Fe and Mn, respectively) is observed for these, the water quality of the basin waters will be reasonably protected for all uses.

pH

No substance will be permitted which will cause the pH of the receiving water to fall outside a pH range between 6.3 and 9.0. This will provide general protection to public water supplies, to industrial water supplies, to fish and aquatic life, and to other uses.

Suspended Solids and Floating Materials

Substantially complete removal of settleable solids and floating materials will be required to prevent nuisance conditions and sludge deposits. Additional removal of suspended solids may be required to prevent turbidity causing excessive damages to water uses.

Dissolved Solids

Objectives concerning damages from dissolved solids related to toxicity, oxygen depletion, tastes and odors, pH, and color are discussed under other effects. Additional limitations on dissolved solids will be applied to prevent excessive hardness or other damaging effects. Chlorides (as Cl) should not exceed 100 p.p.m. at any location within the basin.

Temperature

Operations resulting in excessive stream temperatures which impair other water uses reasonable and necessary in the public interest will not be permitted.

Fluorides

Although some ground waters of the basin contain significant fluoride contents requiring control within acceptable limits for public water supply purposes, there is no indication, at this time, of adverse influence of fluoride-bearing wastes on surface waters. In case control of this constituent becomes necessary the maximum tolerable at waterworks intakes is fixed at 1.5 p.p.m.

Special Conditions

Insofar as practicable the effect of sewage or waste discharges on the receiving waters shall be considered after they are mixed with the waters and beyond a zone of immediate effect. The extent to which this is practicable depends on local conditions and the proximity and nature of other water uses.

Where limitations on waste discharge are determined by public water supplies and where these limits are more restrictive than for other water uses the objectives shall be applied to conditions at the water supply intakes.

Every effort will be made by the regulatory agencies (a) to preserve the present cleanliness of basin waters and (b) to improve the water quality inso-

far as such action is consistent with the public interest. Objectives as offered, therefore, do not invite the loading of waters to the maximum allowable, but do serve as a guide to a sound pollution abatement and control program.

Deoxygenating Pollution Reduction Requirements

Basically, an evaluation of the factors influencing the self-purification capacity of a stream is essential in the determination of the amount of pollution reduction necessary to meet the requirements for essential water uses. It is generally conceded that the combined effect of the utilization of the oxygen dissolved in the water of a stream and the subsequent reaeration of the water or the absorption of oxygen from the atmosphere, studied through the medium of the oxygen sag curve, can be successfully analyzed within certain limitations.

No mathematical approach, by means of the oxygen sag curve, to the rates of deoxygenation and of reaeration is applicable to streams in which at critical flows the dissolved oxygen is entirely depleted or in which oxygen contents above saturation are found; positive dissolved oxygen values within limitation of oxygen saturation are essential. Consequently, in stream zones or in small tributaries where oxygen depletion is complete at critical flows, the best reductions of sewage and industrial wastes practical of attainment are indicated.

Figure 2 and Tables III, IV, and V show that pollution loads are heavy in comparison with the critical flows of these streams. For the most part, under the relatively high stream flows of the period of investigation, oxygen depletion often accompanied by a zone of oxygen supersaturation was experienced on the tributary streams in question. Consequently, at the focal points indicated on these tributaries the best treatment or reduction within the realm of practicability will be essential.

The Maumee River proper, therefore, represents the only stream in the basin that warranted effort toward a mathematical approach to stream sanitation study. For an example, a brief description with conclusions relative to extent of pollution reduction for the Defiance area will be presented.

The field work initially was planned for the collection of data which would be applicable to the use of the LeBosquet method for estimating the required degree of deoxygenating pollution reduction. This method, an abbreviation of the Streeter-Phelps procedure, had been used in the 1949 study of the Miami River (1); had been checked with other methods requiring more detailed compilation of data, more detailed mathematical computations, and/or more detailed correlation of probability factors; and had been considered satisfactory for Miami River conditions. The regulatory agency must depend on the least time consuming procedure if at all possible; a practical working tool is of the utmost importance. During the 1950 period of stream investigation, erratic oxygen depletion data were observed. This was attributed largely to the stream flows, which were above the so-called "drought range." In the late summer of 1951 the stream work at Defiance was repeated when the stream flow was about 300 c.f.s., as compared to the selected critical flow of about 100 c.f.s. Somewhat better results were obtained to indicate oxygen depletion. However, many of these were erratic. Selected data applied to the LeBosquet formula indicated that 85 per cent reduction of pollution loads was necessary. Dissatisfied with this application, the data have been applied to the nomographic solution of the Streeter-Phelps formulas as suggested by Streeter. It should be emphasized that field data had not been collected specifically for this use; k values, for instance, necessarily had to be assumed. The solutions, however, have indicated

1950 pollution load reduction of 50 to 60 per cent.

Factors which have affected what would be considered a reasonably satisfactory stream sanitation analysis are:

1. Physical features, such as the dam at Independence.
2. Sludge accumulations in the relatively quiescent pool behind the dam.
3. Variable loads contributed by industrial establishments.
4. Countercurrents in the pool.

Observations indicated that most probably there are periods when the load to the river at Defiance will exert effects as indicated by the LeBosquet methods; that is, conditions that would substantiate 85 per cent reduction of the 1950 measured load. Furthermore, the nomographic solution (Streeter-Phelps) application indicates that reductions at critical flows must be greater than those which can be accomplished by primary treatment facilities. It appears logical, therefore, to select as an initial requirement a reduction midway of the extremes as indicated by the above applications of the field data collected, namely 65 per cent reduction of the 1950 loads. With partial treatment accomplished, resulting in the elimination of sludge banks and in some leveling out of discharged pollution loads, better opportunity will be afforded to observe the response of the river to the partially reduced loads under drought flows.

Immediately then the requirement for municipalities on the Maumee River proper will be sewage treatment facilities constructed now to accomplish partial treatment (65 per cent) with provisions for extending the plants for higher degrees of treatment if such are found to be necessary in the future. Parallel requirements for industry are fixed. Industrial waste problems, however, are often such that it is necessary to refer to pollution reduction accomplishments in terms of corrective measures rather than in terms of wastes treatment or modification.

The exception to the above requirements for agencies on the Maumee River proper in the Ohio section is the Toledo area. In fixing the requirement in that location consideration must be given to factors other than deoxygenating properties of wastes. Effects on Toledo's waterworks intake, located in Lake Erie about 12 mi. northeast of the mouth of the Maumee River, and the effect on bathing beaches along the shores of Lake Erie are of prime importance. The initial requirement is fixed as 85 per cent reduction of the 1950 load. This, in terms of municipal sewage, determines so-called complete treatment. The city of Toledo is actively progressing in a program to expand the municipal sewage treatment works to meet or to better this requirement.

Inorganic and Other Wastes Reduction Requirements

Practical consideration of the inorganic wastes and wastes of special characteristics in each individual case is essential. The studies indicate that for the critical flows established tolerances to conform to the water quality objectives presented can be obtained and are practical of attainment.

Summary

In summary, justification is had that the water pollution study of the Maumee River Basin furnishes satisfactory data for outlining a comprehensive program of water pollution abatement and control. Stream sanitation involves so many variable factors that it would be folly to endeavor to make exact predictions or to establish exact standards. Rather, an objective is established. It is felt, then, that it can be emphasized with prudence that the study does furnish material for guidance in a reasonable approach to the correction and preservation of the waters of the basin for uses essential in the public interest.

Acknowledgments

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Reference

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SECOND QUARTER SEWAGE WORKS GRANTS BY NPA

Materials allotments granted by the Water Resources Division of the National Production Authority from April 1 through July 1, 1952, on Controlled Materials Plan applications for that period indicate 308 sewage works projects having a total value of $282,252,593. Distribution of the sewage projects and their costs by states is as follows:

State	No. of Projects	Value ($1,000)	State	No. of Propects	Value ($1,000)
Alabama	2	364	Missouri	4	435
Arkansas	2	139	Montana	1	100
California	30	31,786	Nebraska	4	97
Colorado	5	591	New Jersey	10	41,957
Connecticut	2	830	New York	18	9,572 [1]
Dist. of Col.	1	6	North Carolina	2	529
Florida	2	393	North Dakota	5	969
Georgia	3	2,015	Ohio	14	15,353
Hawaii	8	1,573	Oklahoma	8	1,565
Idaho	2	165	Oregon	12	3,513
Illinois	11	13,378	Pennsylvania	27	11,073 [2]
Indiana	6	5,098	Puerto Rico	2	6,574
Iowa	5	1,776	Rhode Island	3	3,507
Kansas	3	558	South Carolina	2	453
Kentucky	1	6,000	South Dakota	4	490
Lousiana	3	1,624	Tennessee	2	2,000
Maine	1	125	Texas	25	4,449
Maryland	12	7,423	Utah	1	160
Massachusetts	5	11,020	Virginia	7	5,740
Michigan	18	81,984	Washington	9	1,607
Minnesota	12	1,887	Wisconsin	12	2,045 [1]
Mississippi	2	440			
			Total	308	$282,253 [3]

[1] Not including value of 1 project.
[2] Not including value of 2 projects.
[3] Not including value of 5 projects.

THE OPERATOR'S CORNER

CONDUCTED BY HERBERT P. ORLAND

HOUSE FLY BREEDING AT SEWAGE TREATMENT PLANTS IN TEXAS *

BY F. J. VON ZUBEN, JR., L. J. OGDEN, AND R. E. PEEL

Vector Control Section, Bureau of Sanitary Engineering, Texas State Department of Health, Austin, Tex.

Due to the rapid growth of Texas cities during and after World War II, some of the sewage treatment plants have become seriously overloaded. The Vector Control Section, Bureau of Sanitary Engineering, of the Texas State Department of Health had occasion to observe extensive and prolific breeding of the house fly, *Musca domestica,* at several municipal sewage treatment plants in 1951.

Fly breeding was found to occur in the following materials:

1. Inadequately digested sludge in sludge drying beds.
2. Lagooned sludge from overloaded plants where the sludge drying bed capacity was inadequate.
3. Detritus accessible to flies.
4. The accumulated scum layer on top of open sludge digestion tanks.
5. The accumulated scum layer in the gas vents of neglected Imhoff tanks.

From observations it was found that house fly breeding at sewage treatment plants is proportional to the amount of incompletely digested sludge that is accessible to flies for a period of 8 days or longer during the breeding season. Detritus, although of small volume in proportion to the sludge, contains sufficient organic material to sustain prolific fly breeding.

Partially digested sludge in drying beds or lagoons will attract house flies, and egg deposition will occur as soon as the sludge dries to the extent that flies can rest upon it, usually within 12 hr. Oviposition continues daily, with the female flies depositing eggs in cracks that occur as the surface of the breeding material forms a hard crust. Thus, egg laying will continue for several weeks, depending on the sludge drying period. Egg deposition may be resumed in dried sludge if it becomes moist again.

Uncovered sludge digesters have been found to collect a 3- to 4-ft. layer of scum at the surface in which extensive fly breeding has been found. This condition has also been observed in the scum that accumulates in the gas vents of neglected Imhoff tanks.

Since partially digested sludge is the result of inadequate digestion capacity, permanent solution can be effected only by the construction of adequate digestion facilities. Usually, municipal finances will not permit prompt construction of new facilities and it becomes necessary to adopt emergency control measures.

Conditions at Corpus Christi

During the summer of 1951, this condition was encountered at Corpus Christi, Texas. Since 1945, Corpus

* From Communicable Disease Center, U. S. Public Health Service, Atlanta, Ga.

Christi has had a rapid increase in its population. As a result, the West Broadway sewage treatment plant became overloaded. The overload on the sludge digesters was 60 per cent; on the filters, 100 per cent; and on primary sedimentation, 30 per cent. The plant was originally built to serve a population of 55,000, but is currently serving more than 100,000 people. Designed to care for a flow of 4.5 to 5 m.g.d., it now has a flow of 8 m.g.d. The sludge digesters only have a capacity of 212,000 cu. ft., whereas 348,000 cu. ft. are needed. Because of inadequate capacity, the sludge drying beds (48,000 sq. ft.) remained full of half-dried sludge at a time when it became necessary for the plant operator to discharge additional sludge from the digesters. Consequently, the material was dumped into an adjacent 20-acre lagoon area. The detritor material, amounting to 40 to 50 cu. ft. per day, also was discharged into the lagoon area.

Fly breeding occurred in the sludge drying beds, the lagooned sludge, and the detritor material. As the plant was located within a 6-min. walk of the heart of the city, high fly densities occurred in the heavily populated business and residential sections of the city.

Chemical Control Measures

Chemical control measures were instituted promptly. These included the use of space and residual sprays, as well as larvicides. Although tremendous numbers of flies were killed and fly densities were greatly decreased in the sections of the city adjacent to the sewage treatment plant, it was quickly apparent that fly densities were not being reduced to the desired level by standard chemical control procedures at the sewage plant. In addition, the cost of the insecticides prohibited their continued use. It became necessary, therefore, to approach the problem in a different manner.

Because a supply of orthodichlorobenzene was available, this chemical was introduced directly into the sludge as it left the digesters, 25 gal. of 100 per cent orthodichlorobenzene being added to approximately 2,700 cu. ft. of sludge. This procedure reduced the fly breeding in the partially digested material to only a minor extent.

Quicker Drying Effective

Inasmuch as the sludge was requiring 3 to 4 weeks to dry sufficiently for removal from the sludge beds, it was obvious that a reduction of the drying time would materially reduce fly propagation. Consideration was given, therefore, to the use of an effective dewatering agent. Available literature (1) (2) indicated that commercial alum, $Al_2(SO_4)_3$, would accomplish the desired results. In addition to being cheap, it was readily available at the local water treatment plant.

The alum was applied by mounting a barrel of the solution (200 lb. of alum dissolved in 50 gal. of water) on the sludge trough and letting the alum water run slowly into the wet sludge as the latter flowed from the trough into the drying beds. Approximately 1 lb. of alum was added to each 100 gal. of wet sludge, or roughly 2 lb. of alum per cubic yard of sludge. The results were spectacular. The sludge depth in the drying bed dropped from 8.5 in. to 4 in. in the first 24 hr. and the sludge surface developed a fairly dry crust. Sludge levels in adjoining beds had dropped less than 1 in. after standing 5 days.

By the addition of alum, the normal sludge drying period was reduced by more than one-half, thereby greatly increasing the capacity of the sludge drying bed. Because the sludge dried rapidly, it was less attractive to flies and also permitted the removal of the material before fly development could be completed. The reduction in fly potential was of such magnitude that a

limited amount of chemical control could now achieve effective fly abatement.

Fly breeding in the detritor residue was eliminated by burial of this material.

San Antonio Experience

At the San Antonio sewage treatment plant, fly infestations in accumulated scum at the surface of uncovered digesters presented a serious problem. This scum had reached a depth of several feet and was breeding flies extensively. The problem was solved by drawing off some of the supernatant liquor and reintroducing it under high pressure onto the scum surface. This enabled the plant operator to break up the scum layer, which in turn destroyed the fly larvae.

The inspection of numerous sewage treatment plants having adequate digester capacity revealed that fly breeding normally does not occur in properly digested sludge.

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TWO INDUSTRIAL WASTE PROBLEMS AT NEW HAVEN, CONN.*

By Kenneth E. Foote

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High Chlorine Demand of Dye Wastes

In 1940, a short time after the Boulevard sewage treatment plant at New Haven, Conn., was put in operation and chlorination was started, it became apparent that something was happening which prevented this plant from meeting the requirements of the State Health Department as to maintaining a 0.2 p.p.m. residual in the plant effluent.

The chlorinators as originally installed were two 1,000-lb. machines, which could be used as single units or together for a total capacity of 2,000 lb. per 24 hr. With the machines operating at full capacity it was impossible to find a trace of residual chlorine in the effluent, except during week-ends or in the early hours of the morning. It was noticed that during these times the sewage was of normal color, but at other times it was highly colored, mostly blue, black, or brown. It began to look as though the color had something to do with the problem.

Tests were then made on the plant influent. It was found that no trace of chlorine residual could be found in the sewage while it was highly colored. This condition existed in samples taken about 25 ft. from the chlorine solution diffusers with the dose at 2,000 lb. per 24 hr.

After making numerous chlorine demand tests at the treatment plant it was found that the demand at times ran as high as 10,000 lb. per 24 hr. As it was impossible to meet this demand with a 2,000-lb. capacity, something had to be done to correct it. The State Health Department was

* Presented at 1952 Spring Meeting, New England Sewage and Industrial Wastes Assn.; Waterbury, Conn.; May 22–23, 1952.

notified and began to help in locating the source of the trouble.

As it was very certain that the color was a dye and the offender, it was decided to take some laboratory equipment in the back of a car and visit the sewers near the only known sources of dye wastes. One was a paper mill making colored blotting paper; the other, a textile dyeing plant. Samples taken and tested for chlorine demand at the paper mill were found to have no demand at all. A manhole was opened on the sewer in front of the textile dyeing plant, close to the point of entry of the wastes into the sewer. The chlorine demands of the samples were so high that it later was found to be more economical to apply the chlorine at the sewage treatment plant rather than to have the dye plant treat its own wastes.

The officials of the dyeing plant were skeptical when told of the trouble they were causing at the treatment plant. In order to convince them, two other steps were taken. The first was a survey of manufacturers in the district who might discharge liquid waste into the sewers. A list of manufacturers in the district served by the treatment plant was procured from the local Chamber of Commerce and their locations plotted on a city map of the district. The manufacturers using dry processes were eliminated. The rest, about 30 in number were visited. Samples taken and tested for chlorine demand were found to be negative.

The State Health Department and the State Water Commission then decided to concentrate on the dye plant, some of their men being stationed at the dye plant for making demand tests and measuring the amount of wastes discharged into the sewer. The latter quantity was found to amount to almost 1 m.g.d., the average flow through the treatment plant being 17 m.g.d. At the same time, demand tests were being made every 30 min. for practically 24 hr. at the treatment plant. A great many of these tests were made simultaneously at both plants and the results plotted on cross-section paper. When the two demand curves were coordinated as to time (there being a 4-hr. lag due to the distance between the two plants), the two curves matched almost perfectly. This was the evidence that convinced the dye plant officials that their waste was responsible for the chlorination difficulties at the sewage plant.

It also was determined from these tests and from the operation of the chlorinators that the demand fluctuated from a low value of 700 to 800 lb. per 24 hr. to a high of 10,000 lb. This was due to the fact that about 50 dyeing machines were in batch operation at the dye plant. The spent dyes and the rinses, which also had a substantial chlorine demand, were put down the drain. In the periods between waste batches the demand dropped to the normal demand of about 800 lb. per day.

This produced a demand curve that resembled a roller coaster. To smooth out this condition the dye plant put a new drainage system in the dye house by which it was possible to divert the waste through two-way stainless steel valves either to the sewer or to two large concrete holding basins in the dye plant yard. In these basins the dye and the first and second rinses for a whole day's operation were to be held and then discharged to the sewer at a uniform rate. Tests indicated that the effluent from these basins would require a capacity of 4,000 lb. for the chlorinators at the sewage plant and the chlorinators were changed to that capacity.

Despite these arrangements the human element entered the picture. The dye machine operators would forget to set the valve in the position to send the dye to the basins and it went to the sewer, with the result that the residual was knocked out at the sewage plant. The State Health Department raised

the effluent residual requirement from 0.2 p.p.m. to 0.4 p.p.m. because of the high demand and the high bacterial counts found in the waters of New Haven Harbor. This resulted in the capacity of the chlorinators being again increased to 6,000 lb. per day. As there were times when a dose of 6,200 lb. would not show a trace of residual, a conference was held with the dye plant officials. It was found that a continuous dyeing machine had been put in operation and the waste from this machine was causing the trouble. Another basin is being built to take care of this additional waste.

As the dye wastes are corrosive and —in sufficient quantities—a deterent to digestion, it is hoped that damage to equipment at the sewage plant or the loss of digestion will not occur. The sodium sulfite or sodium hydrosulfite used as reducing agents in the dye are the factors which reduce the chlorine.

It should be pointed out that the dye plant has been very cooperative and has spent considerable money on this problem. The City of New Haven has also spent a large sum for equipment, etc., and at the Boulevard sewage treatment plant in 1951, for a chlorination period of 120 days (May 15 to Sept. 15) 240,000 lb. of chlorine was used at a cost of $14,000, exclusive of labor for changing the chlorine containers.

Pork Processing Wastes

About two years ago, a pork slaughtering and processing plant located on the shore of the Harbor, into which the wastes from this plant were drained, was forced to abandon these drains due to a major highway relocation project that buried the outlets. It then became necessary to connect this plant with the municipal sewers.

The waste from this plant contains grease, hog hairs or bristles, hog worms, hog toenails, and at times pieces of liver and kidneys. This waste is received at the East St. sewage treatment plant, which handles a daily flow of 12 m.g.d. and is so situated that it is affected by the tide of the Harbor. In fact, the level in the settling tanks rises and falls 6 ft. with the tide, and the levels in the sewers are also affected.

This condition was the major factor in the plant's first encounter with this waste. The sewers were full, due to the tide, and the grease was floating on top of the sewage. Some of this grease may have risen into the lower part of manholes or the main gate into the plant was not open fully and hung down below the level of the sewage, acting like a skimming blade. When the outgoing tide lowered the level in the sewers, this large amount of grease descended upon the bar screens and lodged there. The combination of several barrels of sticky lard mixed with about the same amount of pig hairs took four men over 2 hr. to remove from the screens. The engineer in charge of the processing plant promised to take care of this grease condition, as it was a loss to them to have it get into the sewer. There were a few more batches before the condition was straightened out, but none as bad as the first one.

While the treatment plant no longer gets the grease and hair in batches as at first, a sizable amount still trickles in. This is evidenced by the large number of plugged sludge lines, trouble with sludge withdrawals from the settling tanks, and also difficulties with vacuum filtering of the raw sludge. In all these cases there were indications of grease and hair. The toenails, hog worms, and other parts of the pig do not interfere with the operation of the treatment plant too much, but it means that additional screenings must be taken care of.

The bottoms of the settling tanks used to be bare when they were drained, but now there remains a rather hard layer of slippery grease on the tank bottom. This makes it difficult for men to work in the tank until the bottom is cleaned with ice scrapers.

As much as two truck loads of this material have been removed from a single tank in this way. Recently there has been difficulty with sludge withdrawals, due to its consistency and the hair in the sludge.

The operation of the vacuum filters has been retarded by grease and hair. The grease causes the cloths to blind and loss of cake on the filters. This requires frequent washings and changes of filter cloths.

Another difficulty has been the combining of conditioned sludge and hair in the filter trough to form a dough-like mass that would move one way with the filter agitator but would not go back, with the result that it would pile up and roll out of the trough onto the floor. This material also causes stoppages in the sludge and drain lines to and from the filters.

State Health Department and State Water Commission representatives and the writer have had several conferences with the officials of the processing plant. Each one has helped some to overcome this problem, but it is not completely solved at present.

The processing plant has been cooperative on all complaints and has installed at the plant a pumping station, settling and skimming tanks, fine bar screens, and mesh screens on the overflow to the killing floor drains and the scalding tanks.

INDUSTRIAL WASTE PROBLEMS AT THE HARTFORD SEWAGE TREATMENT PLANT*

By George Lebetkin

Chemist, Sewage Treatment Plant, Hartford, Conn.

The Hartford (Conn.) Metropolitan District sewage treatment plant has a tied-in population estimated at 220,000. The design population is 300,000; 39 m.g.d. is the designed dry-weather flow. In 1951, the plant treated 31.16 m.g.d. The plant has been in operation since 1938, and the records indicate several industrial waste discharges worthy of note. It is a primary plant consisting of a 4-in. rack, four ¾-in. mechanically-cleaned screens, screenings shredder, grit channels, influent aeration followed by sedimentation tanks, four digesters of 1,800,000-gal. total capacity, countercurrent elutriation tanks, and vacuum filters. About 50 per cent of the tributary area is served by a combined sewer system, the remainder by a sanitary sewer system.

In 1950, the District adopted an ordinance defining permissible wastes that might be discharged into the system to the end that sewage treatment processes might not be disturbed, structures damaged, cost of plant operation increased, or plant personnel or public endangered or harmed. The District was influenced by the model ordinance (1) published by the Federation. Since adoption, the ordinance has proved helpful in guiding policy and backing up decisions when brought to the attention of actual or potential offenders.

Gashouse Wastes

Since 1938, the plant has had several instances where gashouse wastes were collected with the raw sludge, and once when they upset sludge digestion. This tar, containing phenol, may be detected by odor in the rack house, but

* Presented at 1952 Spring Meeting, New England Sewage and Industrial Wastes Assn.; Waterbury, Conn.; May 22–23, 1952.

is generally overlooked. Its specific gravity is usually greater than 1.0 but less than that of raw sludge. It has a typically oily black color with a persistent characteristic odor. In most cases, its presence in the plant was first noted in the laboratory upon inspection of the day's batch of hourly raw sludge samples. By that time the discharge was usually over, but the gas utility was notified and the plant was by-passed for a while.

On January 31, 1951, the last such incident occurred. The utility admitted the possibility of only about a 20-min. discharge, yet for three days after this each hourly raw sludge sample was coated with diminishing amounts of tar, probably indicating residual deposition in the sewer slowly being flushed out. Gas production tapered off rapidly.

On December 16, 1946, a similar discharge depressed digester pH's from 7.1 to 6.9; the same on March 11, 1947. Another discharge occurred on November 8–9, 1947, but no pH effects were noted. In the January 31, 1951, incident mentioned previously, however, digestion was retarded. This time, the digesters were laboring under several handicaps to begin with, as follows:

1. Periodic disruption, during subzero weather, of heat to the hot-water coils, due to water in the fuel oil tank.
2. Decrease of heat transfer efficiency, due to scale build-up on the heating coils.
3. Gradual loss of digester capacity, due to build-up of inert solids whose dry solids contents ran from 25 to 30 per cent.
4. Low winter temperature of incoming raw sludge.

The gashouse phenolic-tar discharge was enough to upset digestive activity where the digesters were laboring under unfavorable conditions, whereas the same relative amount of tar in a few earlier instances did not affect digestion enough to disrupt gas production when the digesters were operating under more favorable conditions. (Incidentally, the third of four digesters is now in the process of being dewatered, desludged, and descaled.)

On December 24, 1943, the heaviest discharge occurred. So much tar built up with the raw sludge that it was impossible to introduce it into the digesters without the reasonable certainty of killing all digestion. For one day this sludge was discharged directly into the Connecticut River without treatment. There was no pH effect due to residual wastes getting in. The gas utility admitted responsibility; it was due to some piping failure. The utility, at all times, was most cooperative in seeking out the causes for such discharges and took appropriate action to prevent repetition insofar as it was possible.

Oil and Grease

Oil and grease are not present in undue amount in the Hartford sewage and constitute no particular problem either in removal from the surface of the sedimentation tanks or in the digesters when digestion efficiency is normal. Some cutting oils and other mineral oils are noted at times. The daily estimate of scum pumped to the digesters, dry basis, is 120 lb. Scum is pumped daily in non-freezing weather, not being pumped in winter due to the exposure of scum pumps and piping.

When the heat transfer efficiency of the digesters was good, scum could be digested away practically at will by raising the tank temperatures several degrees. Gradually, it became harder to raise tank temperatures, and, after 1947, this efficiency became noticeably worse.

Yearly, the Hartford plant is shut down for about two months due to the freshet season raising the Connecticut River elevation higher than the effluent weirs. Each year, therefore, four

digesters have to be restarted, using dormant sludge for seed. Beginning with 1947, lime was required to restart digestion. Since 1948 an interesting observation has been made relative to digester scum coming down in gross amounts in digesters whose heat transfer efficiency and capacity were decreasing.

In restarting the digesters, the following steps were taken:

1. Tank temperatures were raised to 90° F. or higher.
2. Raw sludge was added daily, of course.
3. Lime was added sparingly to prevent the pH from dropping too low the first 15 days.
4. No digested sludge "seed" was drawn for the first 15 days.
5. Digester contents were recirculated.

After the pH leveled off around 6.8 to 7.0, it was noted that in about another 15 days—that is, about 30 to 40 days after the reopening of the plant—scum began to break up and pass down through all digester levels. On the surface of the elutriation tanks, a scum blanket from 3 to 5 in. thick built up and passed over the elutriation weirs into the influent line to the plant. Oil interfered with sludge filtration, fouled the cloths, and raised the ferric chloride requirement. Hair and other material, in turn, fouled up the shredder in the rack house.

Thus, relative difficulty in restarting digestion was followed by a bright side wherein digester scum layers were in large part self-purged from the tanks by a minimum two-week period of excessive digester gas formation and other vigorous solids movement. In 1952, relatively little scum was found during the dewatering of three digesters—tanks that were cleaned for the first time since being placed in service in 1938.

Since 1947, daily composites of raw and digested sludge have been composited into monthly batches and chloroform soluble grease determined. The yearly raw figure averaged 24.8 to 27.7 per cent; the digested, 10.5 to 15.6 per cent. It is, of course, no surprise that during periods of scum purge the monthly grease reading in digested sludge climbed to 22.9 per cent, the highest month being 30.4 per cent. Grease has averaged 25 p.p.m. in the raw sludge and 5 p.p.m. in the digested sludge since 1947.

Acid Wastes

Acid wastes constitute no problem at the plant. In 1951, a study was made of acid waste waters from one metal pickling installation that damaged approximately 1,000 ft. of sewer tributary to the East Hartford sewage treatment plant, now under construction. Here acid waste concentrations, supposedly no greater than 0.2 per cent H_2SO_4, in some 9 years disintegrated Portland cement joints of 10-in. sewer tiles, attacked several manhole bases, attacked brick mortar joints near such bases, damaged metal sewer cleaning gear, and deposited enough iron scale to make repeated cleaning of a section of sewer below the steel company necessary. With joints gone and lying in sandy soil, tile sections were undermined and eventually broken. Sand had passed through the open joints into the sewer. When the tile fragments were examined, no Portland cement debris was present, and there was no evidence that such cement may have been freshly broken off during the sewer repair. This is not surprising. Ludwig and Ludwig (2) reported that a steady source of dilute H_2SO_4 of 0.09 to 0.16 per cent concentration will cause a steady disintegration of Portland cement structures.

During the war, the District allowed this company to discharge 480 cu. ft. of 1.0 per cent H_2SO_4 over a 24-hr. period if diluted down to 0.1 per cent, and never more than 0.2 per cent. There is some reason to believe that

the company so complied. Had the ordinance been in force then, such permission may not have been granted from a rational standpoint alone. Tests show 0.22 per cent H_2SO_4 has a pH of 1.47, and 0.098 per cent H_2SO_4 a pH of 1.85. The ordinance gives the lowest acceptable pH as 5.5, and it is so easy to determine pH.

Chemical tests in 1951 made on repeated samples below the steel company revealed $FeSO_4$ in high concentration, there being 3,320 p.p.m. of Fe in solution in the supernatant alone. The pH was less than 3.0. Dried samples taken from the truck loads of silt removed from the sewer by the sewer cleaning crew revealed ample iron scale. Such scale was easily demonstrable. By passing a magnet over the sample, a considerable fraction was picked up.

Upon the District's recommendation, the company installed a grit chamber to remove the scale and steps are being taken to reduce the acidity to acceptable limits. As for the iron in solution, the ordinance limits the amount to no more than 5 p.p.m. To comply, the company would have to dilute its flow up to 500 times. Therefore, it was suggested that a basic reaction process could remove the soluble iron and neutralize the acid at the same time.

It so happens that below the steel mill there is another company bottling chlorine bleach water, ammonia, starch, and bluing. This company also discharges some wastes. Chlorine will oxidize the ferrous iron to the ferric state, and the ammonia and other alkaline wastes tend to neutralize some of the acidic wastes from above. These neutralization products also increase the solids loading. But, until all acidic discharges are stopped at the source, the District is perhaps fortunate in having this second company below.

Flammable Wastes

There have been instances where such explosive material as gasoline or illuminating gas have entered the sewers and where District tests made on the scene certified as to the explosive condition. Such flammables are transitory and do not make themselves noticed by the time the plant is reached. Flushing with a fire hose and natural dilution have served to take care of gasoline, kerosene, etc., and careful removal of manhole covers so as not to cause a spark has supplied enough natural ventilation to clear out illuminating gas. Where personnel are to enter doubtful areas, oxygen deficiency tests, explosimeter tests, and carbon monoxide tests are first made to determine how safe the situation may be. An air blower is employed in addition to natural venting, if conditions dictate. In 1951, two sewer inspectors checking a new line were affected by gas seeping in from broken adjacent gas connections. The District records show no damage to any of the installations due to explosion. The ordinance, of course, forbids willful discharge of flammables.

Miscellaneous Wastes

In addition to the wastes thus far enumerated, at times sewers have been partially obstructed due to (a) chicken feathers from a poultry processor, and (b) inert factory waste silt discharged before a sewer siphon. At one of the pumping stations some trouble has been experienced due to discharge of entrails and hides.

References

1. "Municipal Sewer Ordinances." Manual of Practice No. 3, Fed. of Sewage Works Assns., Champaign, Ill. (1949).
2. Ludwig, H. F., and Ludwig, R. G., "Corrosion of Cement—Bonded Sewer Pipes." *Water and Sew. Works*, **98**, 9, 404 (1951).

PRACTICAL RESULTS OF ALKALI-CHLORINE TREATMENT OF CYANIDE WASTES *

By I. D. Cox

Supervisor, Water and Industrial Waste Treatment Plant, Ford Motor Company, Monroe, Mich.

The Ford Motor Company plant at Monroe, Mich., has what is thought to be the only combined water softening and plating wastes treatment plant in the world. The waste treatment plant was designed to handle all waste rinse waters and discarded plating baths from one of the largest plating installations in operation. The plating department has a capacity of over 13,500 sq. ft. per hour, which includes copper, nickel, zinc, and chrome plating of about 55 different automotive parts.

Treatment Details

The design basis for the cyanide treatment plant was a normal rinsewater flow of 100 g.p.m. with a concentration of 25 p.p.m. of cyanide as CN. Due to changes made in the plating operations, this flow has increased to 450 g.p.m., but the concentration has decreased to a maximum of 4.8 and a minimum of 0.3 p.p.m. as CN.

The treatment plant consists of three holding tanks, each with a capacity of 22,000 gal. and equipped with a mechanical mixer and a skimmer for oily wastes. Two chlorinators, each with a capacity of 6,000 lb. per day, and two lime slakers, each with a capacity of 500 lb. per hour, are the chemical feeders used. Chlorine is obtained in 1-ton containers. Lime is purchased in bulk.

The alkaline chlorination method of cyanide treatment has been found very effective at this plant, producing an effluent that has shown no deleterious effect on the receiving stream. The waste cyanide is oxidized to cyanate, which in turn is oxidized to carbon dioxide and nitrogen (1). Lime is fed into the waste above the liquid level and chlorine is applied to a point directly below the mixer, which is about 2 ft. from the bottom of the tank. Good mixing has been achieved throughout the tank and at no time has there been any evidence of local acidification on addition of chlorine. Occasionally, however, some chlorine odor is noticeable over the surface of the waste during treatment.

In the purification of the plating solutions, powdered activated carbon is used. This carbon is then received in the treatment plant with concentrated waste. The carbon and other suspended solids increase the chlorine consumption considerably. The actual amount of chlorine used, both in the laboratory and in plant practice is about 20 p.p.m. to 1 p.p.m. cyanide, or about three times the theoretical amount of 7 p.p.m. This additional chlorine also requires more lime to maintain a pH of 8.5 to 9.0 during treatment. On a laboratory scale it is possible to destroy the cyanide with 8 p.p.m. chlorine when the suspended solids have been removed, or very close to the theoretical amount. More study is to be directed toward the practicability of removing the carbon from the waste before treatment for the cyanide.

The use of the waste as the chlorinator injector water is considered, but was abandoned because of the difficulty expected with suspended solids. If the waste were reasonably free of suspended material this could be done and the treatment time would be reduced materially. The large amount of chlorinator water is a significant factor in the quantity of waste that can be

* Presented at 1952 Annual Meeting, Michigan Sewage and Industrial Wastes Assn.; Traverse City, Mich.; May 19–21, 1952.

treated in each batch. If the concentration of cyanide is 300 p.p.m. the time required for treatment is about 3 hr.

During the 15 months of operation the waste cyanide treated has been about 0.5 m.g. per month with a maximum concentration of 1,250 p.p.m. The treated effluent enters the Raisin River about one-half mile above Lake Erie.

There has been some question as to whether the treated waste might revert back to cyanide in the stream. It is thought that this may happen if the waste is oxidized only to the cyanate, but it has been impossible to measure any cyanide in samples from the river or in the laboratory after treatment.

Conclusion

Although it is felt that adequate control of the effluent from the Monroe plant has been achieved, studies are to be continued to eliminate the suspended solids before treatment for the cyanide. If this can be done the treatment time will be reduced and considerable savings realized on chemical costs. The alkaline chlorination method of cyanide treatment appears adequate and produces an effluent that has shown no adverse effect on the Raisin River.

Reference

1. Dobson, J. G., "The Treatment of Cyanide Wastes by Chlorination." *Sewage Works Jour.*, **19**, 6, 1007 (Nov., 1947).

INTERESTING EXTRACTS FROM OPERATION REPORTS

Attention operators! It will be appreciated if copies of all annual reports of both large and small plants are sent to the Federation office for abstracting in this section of the Journal. Carbon copies of typewritten reports will be promptly returned on request. Please direct annual reports to: Federation of Sewage and Industrial Wastes Associations, Room 325, Illinois Bldg., Champaign, Ill.

Twentieth Annual Operation Report of the DeKalb (Ill.) Sanitary District Sewage Treatment Plant, for the Year 1951 *

By Donald E. Henn, *Manager*

General

Wet weather throughout the entire year was the dominating factor in plant operational difficulties, although these were comparatively few. Rain every few days—and no week without rain—diluted strong sewage during the summer and provided ample dilution water in the river. However, excess rain meant more sewage to pump, a more dilute sewage to handle, prevention of drying of digested sludge on the beds, and rank growth of all lawns and weeds.

Sewage flow was high throughout the year, with no dry period during the summer months. Total sewage treated was 14 per cent above the previous high year and 34 per cent above the previous 10-year average. Only part of the high flow was due to the weather, the remainder being due to an increasing load on the plant.

* For last previous extract see *Sewage Works Journal*, **21**, 6, 1078 (Nov., 1949).

Primary Settling Tank

The average yearly removal of suspended solids was 62 per cent of the raw sewage solids, as determined by hourly composite samples collected between 7 AM and 3 PM twice weekly. Tests indicate removal of 310.7 tons of raw sewage solids during the year, not including secondary tank sludge pumped to the influent channel of the primary tank or solids settled out of digester overflow liquor.

Trickling Filters

The twin dosing tanks, over which a loose board cover is placed during the winter months to prevent ice and frost from forming in the control air pipes, gave considerable trouble in 1950, but were entirely free of trouble in 1951.

The beds themselves operated efficiently and without serious difficulty throughout the year. No evidence of rock spalling in the bed or clogging of underdrains developed, and no ponding was experienced. The beds unloaded late in May and to a much lesser extent in the fall. Due to controlling the waste flow from the local canning plant during the canning season, the load on the filters during the critical summer months was greatly reduced. On November 19th the canning company started to drain its lagoon to the sanitary sewer at a very low rate. At first little effect was noted at the plant, but by December 1 a heavy growth began to form on the filters, efficiencies dropped, and evidence of ponding was noted. The canning company shut off the lagoon on December 4 and the filters unloaded in a few days and rapidly returned to normal operation.

This unit removed an average of 63 per cent of the B.O.D. of the primary tank effluent and 33 per cent of the total B.O.D. of the raw sewage.

Sludge Pump

Diaphragms installed on September 14, 1950, were still in service at the end of the year, having given 16 months of service. The average life of diaphragms in this pump has been 20 months, although the last couple of sets have lasted longer than the average. This could be luck, or better material in the diaphragms.

The pumping schedule in force during the year provided automatic pumping for 15 to 20 min. (depending on the time of year) at 1 PM, 10 PM, and 3 AM by time-clock regulation, and manual operation from 45 to 60 min. at 8 AM. This pumping schedule provides for variation in sewage flow and solids to be handled. The pump is set to deliver 35 g.p.m. to the digester.

Sludge Digestion Tank

Due to the reduced canning load received during the canning season, the digester was able to handle all sludge and the operation plan of using the storage tanks as secondary digestion units was not put to use.

The practice of drawing small quantities of sludge often, rather than large quantities at longer intervals, was continued. Sludge was drawn 26 times

TABLE I.—Summary of 1951 Operating Data, DeKalb (Ill.) Sanitary District

Item	Average
Total rainfall (in.)	36.59
Tributary population	14,000
Sewage flow (m.g.d.):	
Av.	1.82
Max.	2.38
Min.	1.21
Suspended solids (p.p.m.):	
Raw	182
Settled	66
Filtered	57
Final	39
Per cent reduction	77
B.O.D. (p.p.m.):	
Raw	186
Settled	97
Filtered	36
Final	29
Per cent reduction	84
Digester gas produced (1,000 cu. ft. per day)	11.76
Operating cost ($):	
Total	14,359.34
Per capita	1.026
Per m.g.	22.32

in eight months, or about once a week. During the other four months, valves at the digester were set to remove digested sludge from the bottom as raw sludge was pumped in at the top, at regular intervals. The valves would be left in this position for several days at a time to reduce the sludge level in the digester.

Sludge Drying Beds

Eight beds in two batteries were built over an old stone filter at the time the plant was constructed and took the size and shape of this old unit. Three beds were added in 1938 in another battery to dry sludge accumulated in the sludge storage tanks during the winter months. Two beds built in 1946 contain 11,760 sq. ft. of drying area and are really large area, very shallow sludge storage tanks. They have the added advantage: first, of being low in original cost; second, of providing at 1-ft. depth storage equal to one of the two storage tanks; and third, of being useable as drying beds throughout the summer months.

A summary of plant operation data is given in Table I.

Annual Report of the Cranston, R. I., Sewage Treatment Plant for the Year Ended September 30, 1951 *

By Walter C. Anderson, *Superintendent*

General

A major sewer extension during the year resulted in a 38 per cent increase in sewage flow, to the present average of about 2.5 m.g.d. About 50 per cent of the present population is connected to the sewer system, with only about 5 per cent of the flow representing industrial wastes. The plant is operated with full electrical control from the main control desk and is so designed that no actual contact of the sewage by plant personnel is generally necessary.

The plant has more than ample capacity. With the exception of the grit removal, comminutor, and grease removal units, all major units are in duplicate with only one of each unit in use, the other being held in reserve. The blowers supplying the plastic (Saran) diffuser tubes can produce 4 cu. ft. of air per gallon of sewage at the present rate of flow.

The operating staff consists of a superintendent, a foreman, a filter operator, a chemist, six operators, and one laborer.

During the year a combination gas-oil unit was installed in the hot-water boiler used for digester and building heating. Actually, only 41 per cent of the 10,000,000 cu. ft. of digester gas produced was required for plant needs, the remainder being burned in the waste gas burner.

Grit Removal

Reduction of grit removed from 2,640 cu. ft. for the previous year to 1,794 cu. ft. for the current year, despite the increased flow, can be attributed to improved operation of the organic return pump because of prescreening of rags.

The combs, cutters, and bottom seal of the comminutor were replaced during the year. This unit has operated continuously with little attention except for regular periodic servicing.

Primary Scum Removal

Scum removal equipment on the primary settling tanks operated efficiently during the year. The usual practice of

* For last previous extract see *Sewage Works Journal*, 19, 2, 278 (Mar., 1947).

pumping the entire contents of the scum well, whenever full, directly to the digesters was modified. It had been observed that the actual scum accumulation in the scum well, even when full, appeared to be less than 1 in. in depth. The scum well bottom liquor, therefore, was returned to the primary tank inlet for recirculation, only the upper layers being pumped to the digesters. During the year, a volume reduction of 85 per cent over previous scum pumping practice was effected, with only 24,300 gal. (compared to 161,820 gal. for the previous year) going to the digesters.

Aeration Tanks

The Saran diffuser tubes delivered more air during the entire year than the design requirements, indicating the tubes to be free from any clogging material. The blowers have been operated more than 43,000 hr. each, and both are in excellent condition.

Final Settling

Some interesting measures were tried during the year. In an endeavor to find some solution to the spasmodic discharge of fine sludge particles over the effluent weirs, the second tank was placed in parallel operation with the first. As long as the detention period did not exceed 4.5 hr. the problem seemed solved. During extreme dry-weather flow, however, with its consequent increase in detention period, the pH dropped and an increase in chlorine dosage from 70 to 125 lb. per 24 hr. was required to maintain a residual of 0.5 p.p.m. at the outfall.

Digesters

A decided drop in digester performance was caused by excessive amounts of mineral oils contained in industrial wastes. In the space of one month, gas production dropped from 30,000 to 170 cu. ft. per day and serious loss of heat transfer efficiency was noted. The digester was emptied and

TABLE II.—Summary of Operating Data for the Cranston, R. I., Sewage Treatment Plant for the Fiscal Year 1950–51

Item	Average
Trib. pop., est.	27,765
Sewage treated, total (m.g.)	896.2
Sewage flow (m.g.d.)	2.46
Per capita (g.p.d.)	88
Indus. wastes (%)	5
Grit (cu. ft./m.g.)	2
Grease (gal./m.g.)	61
Primary settling data:	
Det. period (hr.)	1.66
Sludge (gal./m.g.)	5,853
Skimmings (gal./m.g.)	27
Aeration tank data:	
Aer. period (hr.)	6.76
Air supplied (cu. ft./gal.)	1.2
Ret. sludge (%)	28
Mix. liq. susp. sol. (p.p.m.)	1,254
Sludge index	172
D.O., outlet (p.p.m.)	6.1
Final settling data:	
Det. period (hr.)	4.1
Sl. returned, tot. (m.g.)	272
Sl. wasted, tot. (m.g.)	8
Sludge susp. sol. (p.p.m.)	1,354
D.O., effl. (p.p.m.)	5.5
D.O., sludge (p.p.m.)	4.1
Chlorination data:	
Total used (lb.)	24,717
Applied (p.p.m.)	3.0
Residual (p.p.m.)	0.62
Sludge digestion data:	
Sl. to dig., total (m.g.)	5.25
Solids (%)	3.51
Gas produced:	
Total (mil. cu. ft.)	10.17
Per m.g. sewage (cu. ft.)	11,350
Per capita daily (cu. ft.)	1.1
Vacuum filtration data:	
Dig. sl. to filt., tot. (gal.)	943,975
Solids (%)	3.68
Vol. solids (%)	55.7
Filter cake, total (tons)	537.64
Cake moisture (%)	76.3
Cake dry solids, tot. (tons)	124.66
$FeCl_3$ used, tot. (lb.)	17,876
Ratio, $FeCl_3$-dry solids (%)	6.88
Filter rate (lb./sq. ft./hr.)	2.46
Suspended solids:	
Raw sewage (p.p.m.)	184
Final effl. (p.p.m.)	13
Reduction (%)	93
5-Day B.O.D.:	
Raw sewage (p.p.m.)	207
Final effl. (p.p.m.)	21
Reduction (%)	90
Operating cost ($):	
Total	54,420.76
Per m.g. treated	60.74

⅛ to ¼ in. of scale was scraped from the heating coils. Within another month, the digester was at full production. In the meantime, the industry causing the difficulty succeeded in reducing its oil loss from more than 100 p.p.m. to 9 p.p.m.

Both digesters are now being operated in parallel. One is getting all the oil segregated in the grease removal unit, the other being carefully kept as free of oil as possible, to act as a control. Slightly more than 22,000 gal. of "grease" have been added to the test digester with no noticeable adverse effects.

A summary of the operating data for 1950–51 is given in Table II.

Annual Reports of the Green Bay (Wis.) Metropolitan Sewerage District for the Years Ending March 31, 1950 and March 31, 1951 *

By George W. Martin

Chief Engineer and Superintendent

The sewage flow in 1950 was almost identical with that of the preceding year, but in 1951 it increased by 0.4 m.g.d. In addition, 496 m.g. of storm water was by-passed through the master control pumping station.

The power used at the sewage treatment plant amounted to 327 kw.-hr. per m.g. treated in 1950, with 103 kw.-hr. per m.g. used for pumping by-passed flow. In 1951 these power consumption figures were 335 and 114 kw.-hr., respectively. Of the total 1,105,744 kw.-hr. consumed in 1951, all but 120,400 kw.-hr. were produced by the District's gas-engine driven generators.

Plant Heating

Practically the entire heat requirements of the plant were satisfied by the reclaimed heat from the gas-engine cooling system. Additional heat required was derived from the gas-fired boiler and an auxiliary coal-fired boiler. The entire fuel bill for 1951 amounted to only $341.75.

Experimental Filters

Early in 1949, two additional experimental filters (8-ft. diameter) were built, one of 6-ft. depth, the other of 1.5-ft. depth. Except for depth, these units were identical to the original two 3-ft. deep units operated the previous year. All four units were placed in operation on May 18, 1949, at 11-m.g.d. flows and high loadings (about 0.5 lb. of B.O.D. per sq. ft.). Under such operation, the unit did not properly condition and reductions were poor. Reduction in loadings brought the units to satisfactory condition. Yeast waste (1 yeast to 10 sewage) applied to one of the 3-ft. deep units caused deterioration of the filter growth and ponding.

The 6-ft. deep filter was kept in operation at various rates until October 11, 1949, when it was put on a 9-m.g.d. rate, and continued at that rate until October 14, 1950. During this 369-day period, the unit demonstrated that a 6-ft. deep filter loaded at not to exceed 0.5 lb. B.O.D. per square foot per day would satisfy the District's requirements.

Operation data for the two fiscal years ending March 31, 1951, are summarized in Table III.

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* For last previous extract see This Journal, **22**, 1, 116 (Jan., 1950).

TABLE III.—Summary of 1949–50 and 1950–51 Operating Data, Green Bay (Wis.) Metropolitan Sewerage District

Item	1949–50	Average	1950–51
Rainfall (in.)	25.87		28.77
Tributary population, est.		60,000	
Sewage flow (m.g.d.)	8.67		9.05
Storm water by-passed, tot. (m.g.)	385.58		496.04
Screenings (cu. ft./day)	14		16
Grit (cu. ft./day)	30		31
Raw sludge, total dry sol. (tons)	2,779.8		2,881.4
Dry solids (lb./day)	15,232		15,788
Vol. dry sol., total (tons)	1,763.4		1,964.2
Vol. dry sol. (lb./day)	9,663		10,763
Sludge gas (cu. ft. per day):			
Produced	78,344*		93,872*
Consumed	83,733*		102,273*
H_2S (gr./100 cu. ft.):			
Max.	74		80
Min.	13		8
Digested sludge withdrawn:			
Wet sludge, total (cu. yd.)	12,779		13,625
Moisture (%):			
Max.	94.9		93.9
Min.	83.6		87.6
Vol. matter (%):			
Max.	58.4		66.7
Min.	36.1		30.5
5-day B.O.D. (p.p.m.):			
Influent	260		239
Final effluent	197		171
Reduction (%)	24.3		28.4
Suspended solids (p.p.m.):			
Influent	216		261
Final effluent	95		107
Reduction (%)	56.0		58.8
Chlorine:			
Total used (lb.)	0		60,000†
Max. dosage (p.p.m.)	0		14.7
Electrical energy (kw.-hr.):			
Produced by plant, total	988,654		1,053,163
Consumed, total	1,020,967		1,105,744
Operating costs ($):			
Total	56,925.96		63,436.75
Per m.g.	16.04		19.21

* Metering error. † Four months.

SAND AND SILT PROBLEMS AT TOLEDO, OHIO *

By A. H. Niles

Engineer-Superintendent, Division of Sewage Disposal, Toledo, Ohio

Toledo, Ohio, has some very bad ground conditions, particularly in the northwestern part of the city where a considerable amount of quicksand was encountered when sewers were constructed. As a consequence, there is more infiltration from this area than from most others. The finely divided sand and silt enters the imperfect joints whenever the ground water rises above the sewer invert. If the sewer

* Presented at 1952 Annual Meeting, Ohio Sewage and Industrial Wastes Treatment Conference; Toledo, Ohio; May 21–23, 1952.

passes through a pocket of this material it may enter only for a relatively short distance.

The sand is then carried along until it reaches a place where the velocity of the water decreases to the point where gravity will allow the material to settle and form a deposit or bank. Then, when there is a rain, or flow in the pipe is increased to a point where scouring action takes place, the silt moves downstream. It is then carried to the interceptor, where it may resettle and form new deposits, perhaps with organic material, to form sludge banks. When the flow is increased in the interceptor, the same thing recurs and this low volatile solids sludge reaches the plant.

When the flow reaching the plant is at the rate of 75 m.g.d. or more, the velocity through the detritors is too great to allow the very finely divided silty material to settle out. It is then carried over into the clarifiers, where it cannot help but settle out. Once it has settled in the clarifiers it must necessarily be pumped into the digesters.

The surprising part is the length of time it takes for the silt to pass from the top, where it enters the digesters, to the bottom, where it causes overloads on the mechanism. This time varies somewhat from digester to digester due to the amount each may receive and the amount and character of the sludge which it contains. It usually takes from 4 to 8 or 9 weeks to concentrate to a degree where the mechanism shows the effect of trying to move the heavy, viscous material from the periphery of the tank to the center by means of the blades attached to the two scraper arms. The only way to relieve this overload is to try removing it through the sludge suction line connection to the cone. However, if the pump is operated at too fast a rate, it will pull lighter sludge through this heavy layer. If operated at too slow a rate, the heavy sludge, sand, and silt tends to settle in the long sludge suction line to the pumps, located in the digested sludge pumping station, and clog it. The best way to overcome this problem is to keep the mechanism running and pump out the heavy material to the marsh as fill.

Enormous pressures build up in the compression spring at the end of the worm shaft as a result of the resistance effort applied all along the two 42-ft. lever arms, as transmitted through the 7-in. solid vertical shaft and worm gear of the digester mechanism. This is sometimes so great as to break balls in the thrust bearing at the end of the shaft. The pieces from one or more of these broken balls may work out into the sleeve bearing bushing and cut it so that it must be replaced and perhaps also have the shaft turned down.

This occurred once when it was impossible to get the machine work done and the parts replaced without leaving the mechanism down over the week-end. When the worm shaft, sleeve, and thrust bearing were finally replaced, the silt had compacted to the point where the overload trip switch would not allow the motor to run. In the past it has sometimes been possible under somewhat similar conditions to get the mechanism started by repeatedly reversing the motor through a double-throw switch. This time nothing availed, although the tank was pumped down as far as possible and filled with river water, the process being repeated several times. At last we had to give up until a 4-in., 210-g.p.m., portable, screenless ejector pump with an explosion-proof electric motor could be purchased after a delay of some 6 months. This pump was then lowered into the digester through the gas dome.

Pumping was started and the digester was emptied to a point where a nozzle on the end of a fire hose could sluice the silt to the suction side of the pump. The digestion tank was completely emptied with about a week of daytime work.

As both the dry-weather and storm flows to the plant increase, there will be cases of this nature occurring more and more frequently.

TIPS AND QUIPS

Near Tragedy in Michigan

A symposium of reports on recent accidents connected with sewage treatment and allied works was presented at the 1952 Annual Meeting of the Michigan Sewage and Industrial Wastes Association, held May 19–21, 1952, at Traverse City, Mich. As a participant in this symposium, C. T. Mudgett, superintendent of the Muskegon sewage treatment plant, presented the following:

It was a Saturday morning in February and about enough time remained for the Water Department crew to check the 24-in. valve. There are many turns to close and then open a 24-in. gate valve and the crew was anxious to get the job done.

The cover on the valve vault was covered with 3 or 4 in. of gravel, which was frozen solid. It was broken out with an air hammer, the cover was removed, and one man immediately entered. He read the name plate on the valve to determine the direction he should turn the wheel and while he was doing this he felt peculiar and wondered what was the matter with him. Then he decided he would get out, but he didn't make it. When he did not answer calls of the fellows on top, one entered to find out why. When he got to the bottom he saw that the first had passed out, and called for a line. The line was obtained and another entered to help. The second had passed out, and the third that entered did likewise.

Fortunately, the truck was equipped with two-way radio and the remaining members of the crew called the Fire Department. In 5 min. the emergency squad was on the spot and with oxygen masks entered the valve vault and removed the unconscious men. All were given oxygen at the hospital and recovered.

After the men were removed, the writer was called to test the air in the vault. He had only an explosimeter, which showed explosive gas present at just under the lower explosive limit. This was after three men had entered and passed out, and two firemen had entered and removed the unconscious men. This activity had no doubt mixed fresh air with the bad.

The vault was newly constructed (that is, within the previous year) and was dry and clean. It looked safe. Where would explosive gas come from? The local gas company that afternoon found a small leak in the gas main near the vault. The leak was repaired and the following Monday no trace of explosive gas could be found in the vault. It is believed that gas from the small leak in the gas main followed the freshly filled trench and slowly filled the vault. The frozen cover held the gas and prevented fresh air from entering. The natural gas from the main was not in sufficient concentration when the test was made to create the oxygen deficiency which must have existed when the men entered, but it must be remembered that the test was made after considerable circulation of air.

The really fortunate parts of this near tragedy were that there was a radio on the truck, and that the fire department was equipped with the proper (oxygen type) masks and "know how," gained from experience which did not end so fortunately, to remove the stricken men promptly.

Sludge Pump Lubricant

The sewage treatment plant at White Hall, Ill., was giving trouble with lubrication of a piston-type sludge pump running at 155 r.p.m. and rated at 40 g.p.m. at 40-ft. head. This pump has an oil well around the top of the cylinder, but the recommended oils seemed to turn to jelly that gave no lubrication, permitting sludge to leak out of the cylinder top and necessitating frequent replacement of the packing.

After trying several different types of lubricants, Superintendent W. E. Settles found that 1 qt. of 90-weight gear lubricant, cut with ¼ pt. of No. 20 detergent motor oil, gave very good lubrication. Apparently the motor oil must be of the detergent type.

As reported in the May, 1952, issue of *The Digester*, with use of this lubricant the pump has operated for 3½ years without any trouble or repacking.

Do's and Dont's for Hoists

1. Keep equipment clean, lubricated, and tight.
2. Don't exceed rated capacity.
3. Inspect cables or chain periodically and change when wear becomes excessive.
4. Don't make lifts or pulls that pull hoist or hooks out of line.
5. Don't bump or knock the hoist housings.
6. Replace bent hooks or rings.
7. Check brake operation frequently on motor-operated hoists.
8. Be sure the hoist has the capacity and characteristics for the job.
9. Proper hoist selection saves production time and lengthens hoist life.

"Pistol" Torch

Savings in time and money, and greater fire safety, are claimed by the manufacturer of an automatic acetylene-air gas torch recently announced. The pistol-shaped "Torch-O-Matic" lights at a squeeze of the trigger and shuts off on release, eliminating separate operation and equipment for relighting, manual valve adjustment, priming, and warm-up. It is said to be especially well-suited for "on-off" work, such as in many piping, sheet metal, and repair shop jobs. One-hand operation of the 12-oz. torch provides instantaneous heat up to 2,800 degrees.

Full details are available from Velocity Power Tool Company, 7505 Thomas Boulevard, Pittsburgh 8, Pa.

Cathartic Pipe Protection

The availability of M–Q Sewer Cartridges has been announced by Navlet's, 1971 Telegraph Avenue, Oakland 12, Calif. The product, when flushed down the drain in recommended dosages, is claimed to dispose effectively of all roots and other organic matter lodged in sewers and drains.

Don't be surprised if any day now you turn on your radio and hear the following suggested singing commercial:

Oh, it's swoosh—like a covey of partridge—
For whatever clogs your bend
When you use an M–Q Cartridge,
The plumber's second-best friend.

SEWAGE PLANT SUPERVISOR—City of Tucson, Arizona, invites applications for qualified supervisor of activated sludge sewage treatment plant. Salary: Open. Requirements include college graduation with specialization in civil or sanitary engineering, and administrative experience in sewage plant operation. Apply to Civil Service Commission, City Hall, Tucson, Arizona.

Reviews and Abstracts*

Summary Report on Water Pollution: Colorado River Drainage Basin. U. S. Public Health Service Publ. No. 110 (1951).

This sixth of a series of 15 major basin reports estimated that in July, 1950, sewage treatment projects costing $11,000,000 were needed at 118 municipal locations in the Colorado River drainage basin for proper pollution control in an area extending to 7 states. However, it is noted that since the original data were tabulated conditions have improved by reason of new or improved waste treatment facilities at several key locations in the basin.

A total of 193 municipalities, institutions, and sanitary districts have sewer systems serving populations totalling 593,000. These systems also handle some industrial wastes. Additional industrial plants known to discharge wastes to the river system number 330, but treatment facilities needed are unascertainable from present data.

The 118 required municipal projects include 34 new plants, additions or enlargements to 30, and replacement of 54 plants. No projects are required at 75 municipal locations, with one other location having undetermined requirements. Treatment facilities are provided at 159 municipalities and 31 industries.

H. P. Orland

Chemical Precipitation of Sewage. By C. Lumb. *Water & San. Eng.*, 2, 6, 209 (Oct., 1951).

The history of chemical precipitation is reviewed in general and the present-day scope of the use of this process is pointed out. It is stated that in 1937, out of about 3,000 sewage treatment plants in Great Britain, about 10 per cent used chemicals for precipitation of sewage; in a survey made in 1938, of the 143 plants answering the questionnaire, 45 utilized chemical precipitation. The most commonly used chemical was aluminum sulfate followed by lime. It is suggested that to overcome the effect of increasing use of detergents in reducing the efficiency of sedimentation, chemical precipitation may become more prevalent in the future.

H. Heukelekian

Discussion of National Water Policy. A Panel Discussion. *Jour.*, Am. Water Wks. Assn., **43**, 6, 414 (June, 1951).

Dale L. Maffit—The development of the Missouri River Basin by the Army's Corps of Engineers and the Bureau of Reclamation is cited as an example of federal water policy participation. The problems this program has presented to the states of the basin are discussed.

A. G. Matthews—This is a basic review of prior comments on the report of the President's Water Resources Policy Commission, and an effort is made to coordinate and clarify the conflicts of ideas and some widely different ideas of basic principles and objectives. Federal participation and justification of water development projects are prominent items in the discussion.

Fred Merryfield—Development of the Columbia River basin forms the background for these comments, and examples of local conflicts with federal projects are cited. However, the need for cooperative state and federal planning and control of water resources is made clear.

Robert P. Lowe

A Method for Decontaminating Small Volumes of Radioactive Water. By R. A. Lauderdale and A. H. Emmons. *Jour.*, Am. Water Wks. Assn., **43**, 5, 327 (May, 1951).

Investigations at Oak Ridge National Laboratory on the decontamination of

* Please send to Federation headquarters all periodicals, bulletins, special reports, etc., which might be suitable for abstracting in This Journal. Publications of public health departments, stream pollution control agencies, research organizations, and educational institutions are particularly desired. Address such material: Federation of Sewage and Industrial Wastes Assns., 325 Illinois Bldg., Champaign, Ill.

radioactive liquids have led to the development of a compact unit which can be adapted to purify emergency drinking water supplies. Extremely radioactive fission-produced isotopes (approximately 2.5 microcuries per ml.) were treated to give a product containing less than 10^{-4} microcuries of activity per ml. This concentration of radioactivity is approximately one hundredth of the maximum concentration suggested as acceptable for emergency use during a 7- to 10-day period.

The decontamination unit consisted of two sections to obtain the desired results. The first section contained 50 g. of grade O steel wool, 37 g. of calcined clay, and 12 g. of activated carbon. The second section of the unit was a ¾-in. column with a 26-in. length of a mixture of quaternary amine-polystyrene type anion-exchange resin and nuclear-sulfonic polystyrene type cation-exchange resin.

As the effluent from this treatment contained radioisotopes that appeared to be relatively short-lived, the end-point concentration limit of 10^{-4} microcuries per ml. presents little biological hazard. Further experimentation is being conducted to perfect this treatment.

ROBERT P. LOWE

Brine Contamination in the Muskingum River. Report of the Ohio River Valley Water Sanitation Commission. 26 pp., 9 figs., 7 tables (1951).

From data collected by several Federal, State, and industrial sources the staff of the Ohio River Valley Water Sanitation Commission prepared this report on the chloride content of the Muskingum River, a fairly large tributary of the Ohio River, which enters the main stream at Marietta, Ohio.

Main source of the brine waste is the liquid discharge from two industries processing salt brine at sites approximately 220 mi. above the mouth of the Muskingum. The effects of chloride contamination are felt throughout the length of the river. During the 3-week survey, the Muskingum River contributed 1,000 tons of chloride ion to the Ohio River, increasing chlorides in the Ohio River from 26 to 47 p.p.m. and at the same time increased the total hardness of the Ohio River water from 132 to 164 p.p.m.

Chloride concentrations in the Muskingum varied from 200 to 15,200 p.p.m. and slugs of chlorides were noted to pass down the river at the speed of normal river flow, indicating that discharge of chloride wastes was not uniform. It was found that a very close correlation existed between specific conductance and chloride content. A curve was developed relating these two factors, which could be used when a more complete survey was conducted at a later date.

The 125,000 population of the valley could take their water supply from this stream if it were not contaminated with chlorides.

Recommendations of the survey included intensifying research into methods of brine waste treatment, studies of methods of processing salt brine which would eliminate or greatly reduce brine wastes, and good housekeeping practices within present industries. It was also recommended that hardness should be determined in future surveys.

This survey was of a preliminary nature and should serve as a guide to planning more extensive studies. Several tables and curves of supporting data are given.

K. W. COSENS

A Study of the Disposal of Chemical Waste at Sea. BY ALFRED C. REDFIELD AND LIONEL A. WALFORD. Nat. Res. Council Pub. 201, 49 pp. (1951).

The study concerns itself with the effect of discharge of acid wastes in the waters off New York City and the New Jersey shore on the fish population and the chemical effects on the sea water. The waste consists of about 10 per cent ferrous sulfate and 8.5 per cent of sulfuric acid. The quantity is about 4,000 tons per day. The point of discharge is 14 to 15 mi. from the coasts and 13 mi. SE of Scotland Light Ship in 80 ft. of water.

The study of the behavior of the waste in the wake of the barge during disposal operations indicated that the acidification of the sea water was very short-lived because of the great dilution and consequent neutralization with the alkalinity of the sea water. The water was not appreciably modified near the bottom of the sea, nor at any substantial distance from the barge. There was an increase in the turbidity of the water, due to formation of ferric hydroxide in the wake.

Biological observations failed to produce any direct evidence that the popula-

tions of fish or of bottom-living animals are being damaged by the disposal of wastes. Zooplankton in the water directly in the wake are temporarily immobilized, but they recover when the water becomes diluted.

A study of the iron content of the water in the various portions of the area involved, before and after the barging operations, showed no measureable increase, whereas the concentration of iron in the Raritan River and Bay, where the waste used to be discharged, has decreased greatly. No measureable increase of iron on the bottom of the disposal area was obtained.

It was concluded that no undesirable effects have arisen from the disposal operation and that this method of disposal as applied to this particular waste and to this local condition is entirely proper. The disposal area was found to be well chosen.

In a study of circulation of water in New York Bight, the most important generalization in regard to the disposal of wastes at sea was the demonstration of rapid rates of exchange of coastal waters with adjacent parts of the sea. The circulation patterns were quite variable and were associated with oceanographic forces and the winds. The capacity of off-shore water to receive and disperse soluble or suspended wastes without undesirable effects is very great. This does not apply to floating wastes, such as oils or garbage, nor to disposal in confined embayments. Each proposal of disposal at sea should be examined separately and critically as to the character of waste and disposal site in relation to local hydrography, fishing grounds, etc.

H. HEUKELEKIAN

The Royal Commission Standard for Sewage Effluents. By F. W. ROBERTS. *Water and San. Eng.*, **2**, 9, 430 (1952).

The author reviews the Royal Commission Standard for sewage effluent and, on the basis of evidence gathered since that time, casts doubt on the valid use of the dilution formula developed by them on the basis of 5-day B.O.D. The Commission did not take into account the differences in the reaeration rates of various streams on the basis of differing depths and velocities. It is asserted by the author that in cases of low dilution, a high dissolved oxygen content in the effluent is as important as a low B.O.D. It is claimed that the application of the Royal Commission dilution formula to suspended matter content of effluents receiving less than eight times dilution may be more justifiable than its application to the B.O.D. H. HEUKELEKIAN

On the Utilization of Waste Liquors from the Digestion of Straw with Monosulfite. By H. F. BANNINCK AND F. M. MULLER. *Antonie van Leeuwenhoeck*, **18**, 45 (1952).

Sodium monosulfite is used quite extensively in Holland for the manufacture of cardboard, paper pulp, etc., from straw. The present investigation was undertaken to try to eliminate the sulfite from waste liquor with the aid of sulfate-reducing bacteria to convert the sulfate to hydrogen sulfide.

A bottle was filled up with beads to serve as support for sulfate-reducing bacteria, through which the sulfite-containing waste was passed. Gas liberated in this bottle was collected, measured, and analyzed.

The waste had a pH of 9.0, total S content of 550 p.p.m. and sulfite-sulfur of 32 p.p.m. The liquor was passed through the bottle at the rate of 1 l. per day. The pH of the effluent was 6.5. When the sulfate-splitting organisms became established on the beads the effluent contained 100 to 140 p.p.m. of H_2S and no sulfite. The total S content of the effluent had been reduced to 460 p.p.m. It was found possible to convert all of the sulfite in the waste liquor in a short time to H_2S by percolating it under anaerobic conditions through glass beads by the agency of attached sulfate-reducing bacteria. Besides the sulfite, part of the other sulfur compounds in the liquor were converted to H_2S. Methane fermentation of the liquor treated in this manner could be established and the removal of H_2S from the final liquor with iron oxide hydrate could be accomplished if desired. H. HEUKELEKIAN

COMPACT, EFFICIENT SEWAGE TREATMENT PLANT BUILT AROUND P.F.T. FLOATING COVER DIGESTERS

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THRIVING JACKSONVILLE BEACH, nestled against the Atlantic Ocean, about twenty miles east of Jacksonville, can be proud of its efficient sewage treatment plant.

This primary treatment plant, designed to serve a population of 25,000 includes two P. F. T. Floating Covers to fit 45′ diameter digesters. These digesters have a total capacity of 62,618 cu. ft., or 2.5 cu. ft. per capita. Plant was built in 1950.

P. F. T. Gas Safety Equipment has been carefully selected for this plant to insure maximum protection against fire and explosion hazards. Included are two Model 91 Flame Traps, 3″ Pressure Relief Valves, 2″ Waste Gas Burner, Condensate Drip Traps and Pilot Line Flame Cell.

Jacksonville Beach is one of the Florida cities whose citizens can rest assured that they have adequate and economical sewage disposal . . . with soundly engineered, long-serving P. F. T. equipment on the job.

Smith & Gillespie, Jacksonville, were consulting engineers for this project.

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Proceedings of Member Associations

SOUTH CAROLINA WATER AND SEWAGE WORKS ASSOCIATION

The 1952 Annual Meeting of the Sewage Section, South Carolina Water and Sewage Works Association, was held at the Jefferson Hotel, Columbia, S. C., on January 24, 1952. Actions taken included changing the name of the section to Sewage and Industrial Wastes Section.

Officers elected for 1952 were:

Chairman: H. H. Connelly, Newberry.
Vice-Chairman: M. Bright, Lyman.
Secretary-Treasurer: W. T. Linton, Columbia.

The Association held its 1952 Short School at Clemson College, Clemson, S. C., on April 10–12, 1952. Total registration for the school was 138.

W. T. Linton,
Secretary-Treasurer

MICHIGAN SEWAGE AND INDUSTRIAL WASTES ASSOCIATION

The 27th Annual Conference of the Michigan Sewage and Industrial Wastes Association was held at the Park Place Hotel, Traverse City, Mich., on May 19–21, 1952. The total registration of 221 included 172 men and 49 ladies.

The conference opened with a symposium on "Links in the Chain of Authority and Responsibility in Waste Treatment Plant Operation." Speakers representing various phases were Dr. Albert E. Heustis, commissioner, Michigan Dept. of Health; John M. Hepler, director of engineering, Michigan Dept. of Health; Milton P. Adams, executive secretary, Michigan Water Resources Commission; Nicholas Olds, office of the Attorney General, Lansing; Huntley DeLano, superintendent, sewage treatment plant, Grand Rapids; and George E. Hubbell, consulting engineer, Detroit.

A breakfast and round-table discussion on plant operation, held the morning of May 20, was followed by the Annual Business Meeting, at which C. T. Mudgett was nominated to receive the Federation's Arthur Sidney Bedell Award for 1952.

Officers elected for 1952–53 were:

President: W. E. Smith, Detroit.
1st Vice-President: K. Fishbeck, Lansing.
2nd Vice-President: H. Oihlke, Manistee.
FSIWA Director: C. Palmer, Detroit.
Secretary-Treasurer: D. Pierce, Lansing.

A sewage session the afternoon of May 20 heard the following papers:

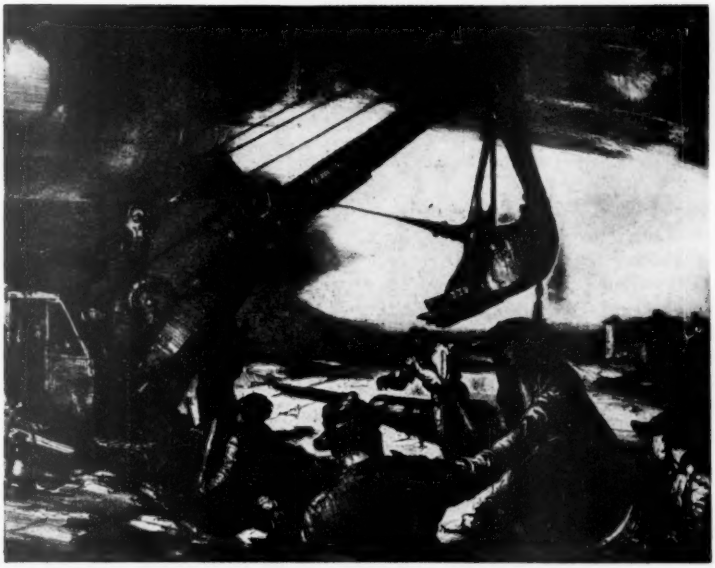
"Plant Operation Experience," by R. A. Greene, Charles Clem, and L. R. Jennings, superintendents at Jackson, Niles, and Owosso, respectively.

"Split Chlorination at Muskegon," by C. T. Mudgett, superintendent, sewage treatment plant, Muskegon.

"Plant Safety," a symposium of reports on recent accidents—at Mount Clemens, by Harry E. McIntee, superintendent; at Lansing, by George Wyllie, superintendent; and at Muskegon, by C. T. Mudgett, superintendent. The closing paper was on "What Can Be Done About It," by Kenneth Robinson, consulting ventilation supervisor, Division of Industrial Health, Michigan Dept. of Health.

A concurrent industrial wastes ses-

(*Continued on page 420a*)



Lithographed on stone for U. S. Pipe and Foundry Co. by John A. Noble, A. N. A.

THIS RURAL SCENE is not an unusual background for cast iron pipe. The installation might be a water supply line for a city nearby. It could be a sewer force main leading to a treatment plant. Also it might be a gas transmission line for a city, in which case it would unquestionably be of the mechanical joint type.

U. S. cast iron pipe in sizes 2-inch through 24-inch are cast centrifugally in metal molds with bell-and-spigot; mechanical joints and plain ends. All sizes of flexible joint and integral flange pipe and all pipe 30-inch and larger are cast by the pit cast process. By whichever process the pipe is made, high quality is assured with the modern control methods employed during its manufacture.

United States Pipe and Foundry Co., General Offices, Burlington, N. J. Plants and Sales Offices Throughout the U. S. A.

U.S. cast iron PIPE

sion on the same afternoon heard the following papers:

"Practical Methods for Reduction of Metal Finishing Wastes Within the Plant," by W. F. Pinner, manager of research, Houdaille-Hershey Corp., Detroit.

"Reduction of Waste Losses by Reclaim Tanks," by C. F. Hauri, plating engineer, Delco-Remy Division, G.M.C., Pontiac.

"Recovery of Chromic Acid Waste Waters by Vacuum Evaporation," by Clark Hathaway, metallurgist, Chevrolet Detroit Forge, G.M.C., Detroit.

"Treatment of Chromic Acid Anodizing Solutions with Barium Chloride," by A. W. Sundwick and John S. Delos, Ternstedt Div., G.M.C., Detroit.

"Practical Results in the Use of Hypochlorite for Cyanide Waste Treatment," by Earl Roy, chief chemist, Pontiac Motor Div., G.M.C., Pontiac.

"Practical Results in the Use of Chlorine for Cyanide Waste Treatment," by I. D. Cox, industrial wastes engineer, Monroe Plant, Ford Motor Co., Monroe.

"Application of Ion Exchange to Chromium Wastes," by C. F. Paulson, Permutit Co., Detroit.

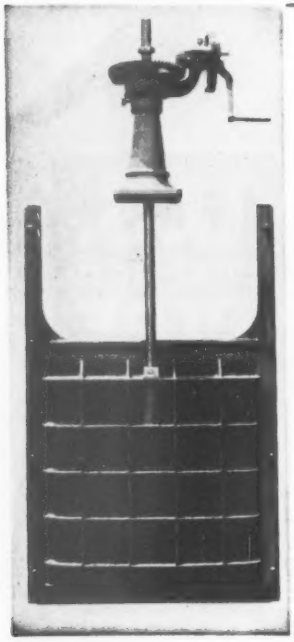
Papers presented at the morning session on May 21 included:

"Biological Effects of Pollution in Michigan Streams," by Eugene Surber, biologist, U.S.P.H.S., Chicago, Ill.

"Appraisal of a Chemical Waste Problem," by Dwight Miller and Leslie Gillett, Sharples Chemicals, Inc., Wyandotte.

"High Water in the Great Lakes," by Dale Granger, hydraulic engineer, Michigan Water Resources Commission, and Clyde Palmer, City Engineer's Office, Detroit.

DONALD M. PIERCE,
Secretary-Treasurer



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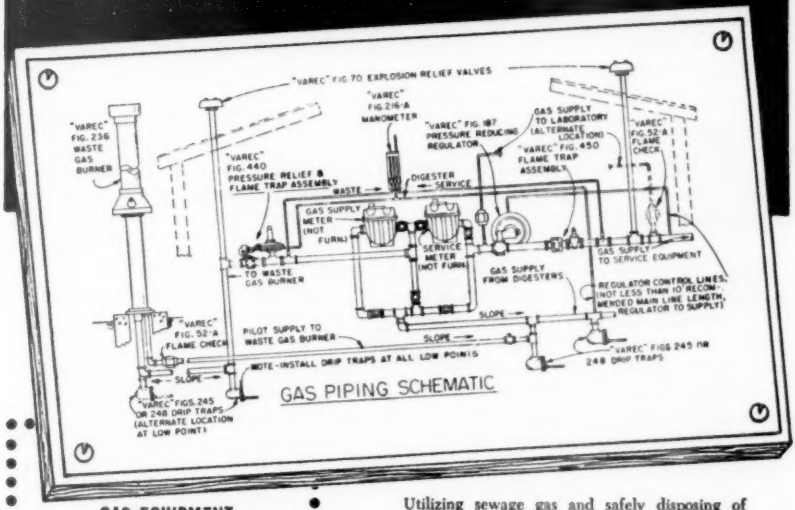
"VAREC" FIG 70 EXPLOSION RELIEF VALVES
"VAREC" FIG. 236 WASTE GAS BURNER
"VAREC" FIG. 216-A MANOMETER
"VAREC" FIG. 97 PRESSURE REDUCING REGULATOR
GAS SUPPLY TO LABORATORY (ALTERNATE LOCATION)
"VAREC" FIG. 450 FLAME TRAP ASSEMBLY
"VAREC" FIG. 52-A FLAME CHECK
"VAREC" FIG. 440 PRESSURE RELIEF & FLAME TRAP ASSEMBLY
WASTE
DIGESTER SERVICE
GAS SUPPLY METER (NOT FURN.)
SERVICE METER (NOT FURN.)
GAS SUPPLY TO SERVICE EQUIPMENT
TO WASTE GAS BURNER
GAS SUPPLY FROM DIGESTERS
REGULATOR CONTROL LINES (NOT LESS THAN 10 TIMES MEDIUM MAIN LINE LENGTH, REGULATOR TO SUPPLY)
"VAREC" FIG. 52-B FLAME CHECK
PILOT SUPPLY TO WASTE GAS BURNER
SLOPE
SLOPE
SLOPE
NOTE - INSTALL DRIP TRAPS AT ALL LOW POINTS
"VAREC" FIGS 245 OR 248 DRIP TRAPS
"VAREC" FIGS. 245 OR 248 DRIP TRAPS (ALTERNATE LOCATION AT LOW POINT)
GAS PIPING SCHEMATIC

GAS EQUIPMENT SPECIFICATIONS

a. **PRESSURE RELIEF AND FLAME TRAP ASSEMBLY**
"VAREC" Fig. No. 440

b. **FLAME TRAP ASSEMBLY**
"VAREC" Fig. No. 450

c. **FLAME CHECK**
"VAREC" Fig. No. 52A

d. **EXPLOSION RELIEF VALVES**
"VAREC" Fig. No. 70-1

e. **WASTE GAS BURNER**
"VAREC" Fig. No. 236

f. **DRIP TRAPS**
"VAREC" Fig. No. 245 (automatic)
"VAREC" Fig. No. 248 (hand operated)

g. **MANOMETERS**
"VAREC" Fig. No. 216A

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Utilizing sewage gas and safely disposing of excess gas is an automatic operation with "VAREC" Equipment incorporated into your sewage plant design. With this equipment, accurate gas pressures are maintained in all service lines. As soon as the digesters make more gas than required for service, the pressure relief valve to the waste gas burner opens to permit safe burning of the excess.

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Chemical Feed Unit—Bulletin 52 gives complete data on a new chemical feed packaged unit for high-pressure controlled feed. Available in both simplex- and duplex-pump models, the units are entirely self-contained.—The Bird-Archer Co., 4337 N. American St., Philadelphia 40, Pa.

Radiation Pyrometers—New 28-page catalog (No. 9300) gives design, installation, and operating data on radiant-heat detectors for high-temperature applications.—Brown Instruments Division, Minneapolis-Honeywell Regulator Co., Wayne and Windrim Aves., Philadelphia 44, Pa.

Bulk Conveyors—A wide variety of applications of conveyors and elevators for bulk materials handling are illustrated in new Book No. 2475. Also given are typical layout drawings, engineering data, calculation tables, charts, and formulas.—Link-Belt Co., 307 N. Michigan Ave., Chicago 1, Ill.

Controller—A new 32-page bulletin (No. 461) describes and outlines applications for eight types of controller instruments. Specifications, air connections, safety shutdown systems, and other engineering data are included.—The Foxboro Co., 26 Neponset Ave., Foxboro, Mass.

Automatic Sand Filter—Revised Bulletin 46A gives installation and operating data, application suggestions, and descriptive details on a line of automatic backwash rapid sand filters for use in industrial and municipal water supply, paper mill white water recovery, and sewage and industrial waste treatment—Hardinge Co., Inc., 240 Arch St., York, Pa.

Fog Spray Nozzle—With atomizing elements machined from stainless steel, the HX15 spray nozzle is suited to a variety of uses where a portable nozzle (light-weight and with garden hose connection) is required to give a carefully controlled spray pattern and volume. Useful in cleaning, washing, brush control, and certain types of fire protection.—Bete Fog Nozzle, Inc., 85 Pierce St., Greenfield, Mass.

Dust Control—Bulletin No. 909A (28 pages) describes dust control equipment and its many applications. Application and engineering data are tabulated according to types of dust and collection requirements.—Pangborn Corp., Hagerstown, Md.

Aluminum Fastenings—New catalog (Ref. No. 543) describes expanded range of stock items in aluminum fastenings, including sizes and types of bolts, screws, self-tapping screws, nuts, washers, rivets, and accessories to meet practically any need.—The H. M. Harper Co., Morton Grove, Ill.

Chemically Resistant Coatings—Technical Bulletin No. 501 shows chemical resistances of various types of "Prufcoat" synthetic resin protective coatings.—Prufcoat Laboratories, Inc., 50 East 42nd St., New York 17, N. Y.

Water and Steam Valves—A new 8-page bulletin (G-3) describes the features of a line of automatic water and steam valves, including float, altitude, check, solenoid-operated, reducing, relief, and non-return valves.—Golden Anderson Valve Specialty Co., 2125 Keenan Bldg., Pittsburgh, 22, Pa.

Loss-in-Weight Feeder—Bulletin 30-H12 describes loss-in-weight gravimetric feeders for dry materials.—Omega Machine Co., 345 Harris Ave., Providence 1, R. I.

Diesel Engines—Bulletin No. 5202 gives engineering data and specifications for Model 65 stationary diesel engine, in 6- and 8-cylinder sizes, in capacities from 580 to 1,500 hp., and as either straight diesel or dual-fuel units.—National Supply Co., Springfield, Ohio.

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CLOW MECHANICAL JOINT 90° ELBOW

CLOW 90° STANDARD FLANGED ELBOW

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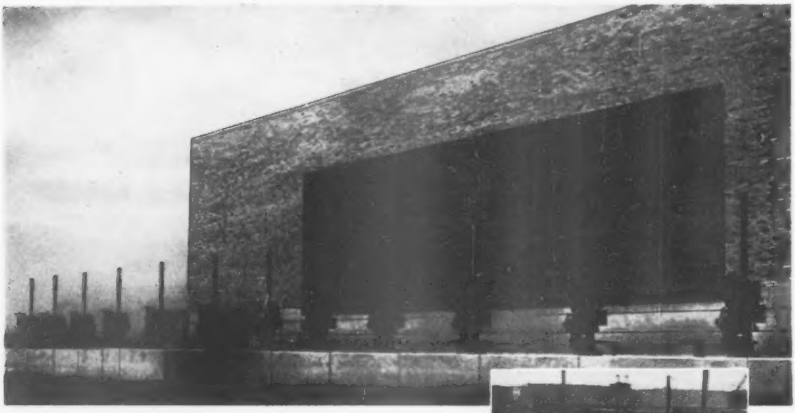

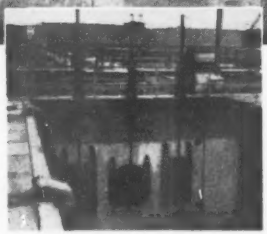

CHAPMAN SLUICE GATES at Hunt's Point.

Above is the Hunt's Point Plant of the New York City Sewage System . . . showing the motor-operated CHAPMAN Sluice Gates controlling the grit chambers.

Begun in the early 1930's, construction and operation of New York's City's Sewage Treatment Works have done wonders to mitigate the pollution of Metropolitan waters.

And in all of these modern plants, you will find many types of Chapman material . . . Sluice Gates, Cone Valves used as check valves, Iron Body Gate Valves...and many different types of operating mechanisms such as floor-stands, motor units and hydraulic cylinders.

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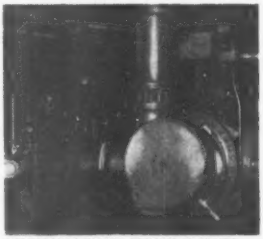

CHAPMAN CONE CHECK VALVES on Raw Sludge Pumps at Rockaway Plant.

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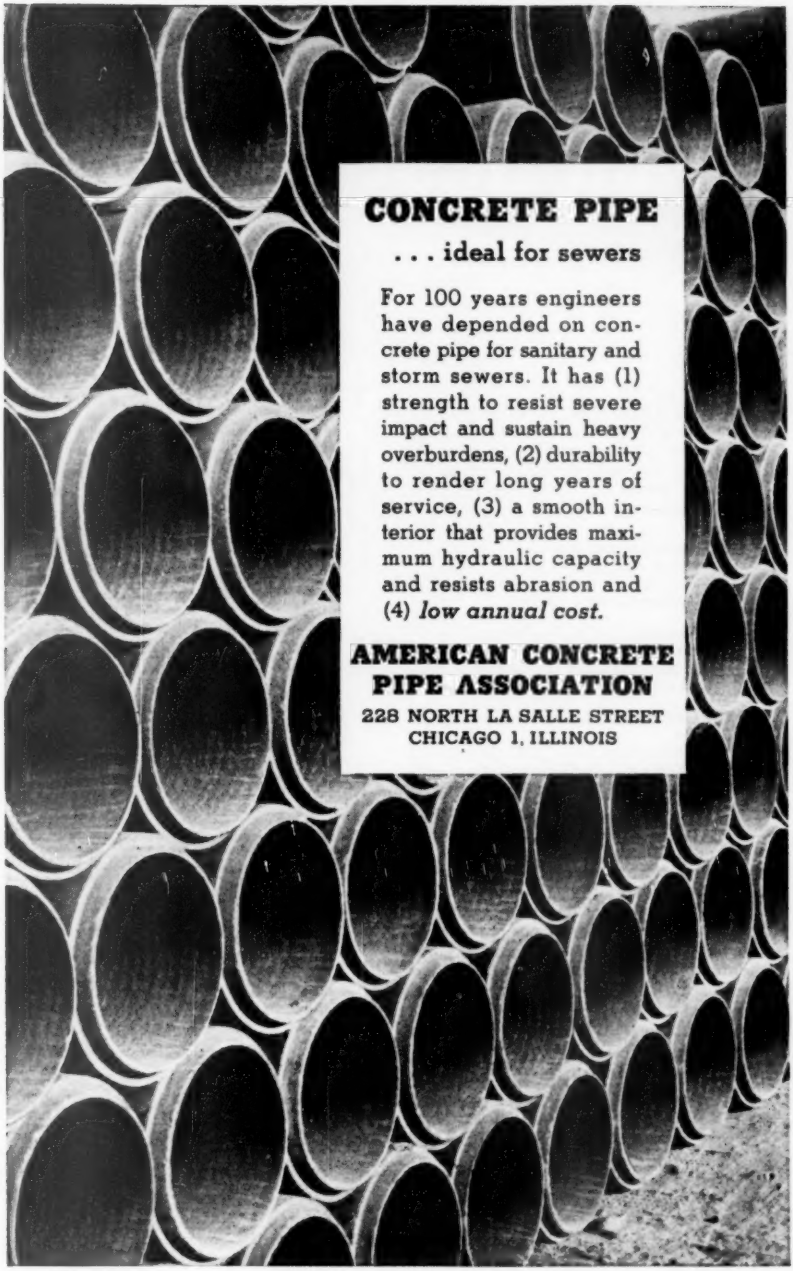
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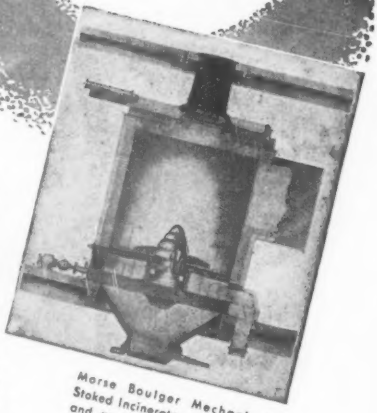

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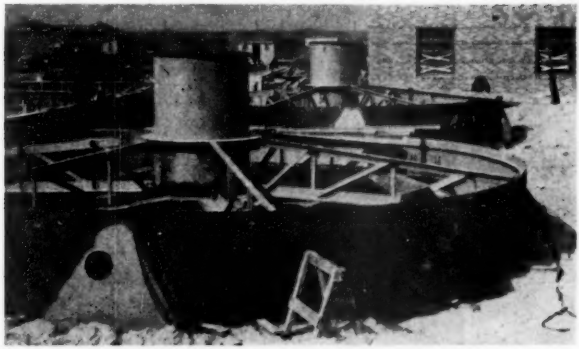

Two 25 ft. Floating Roof Digesters (erection view) at Jones Beach State Park, N.Y.

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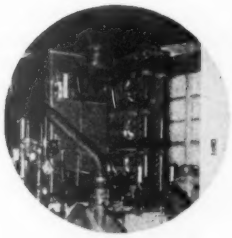

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Photograph shows an Oliver Precoat Filter handling industrial wastes.

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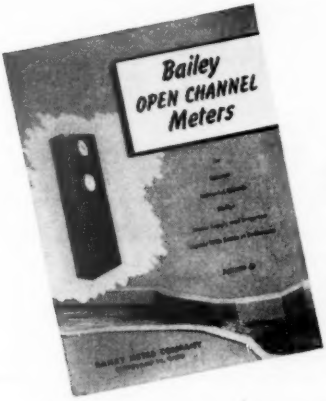

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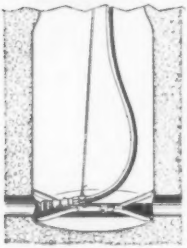

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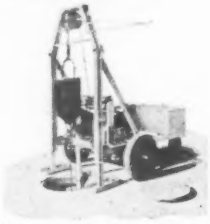

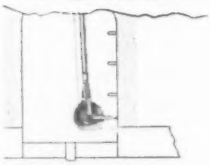

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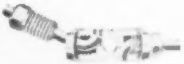

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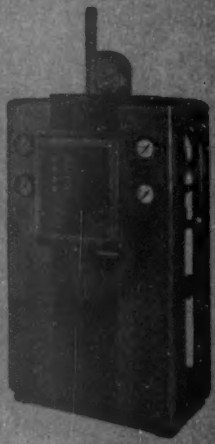

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